Annual **Report**

20
23

FRANCE
ENERGIES
MARINES

CONTENTS

INTERSECTING PERSPECTIVES BETWEEN...

Herveline Gaborieau *- Executive Director of France Energies Marines*
Ronan Stephan *- Chairman of France Energies Marines*

What are your top takeaways from 2023?

Herveline Gaborieau: A key highlight of 2023 was the purchase of the met mast off Fécamp, a major asset for developing large-scale R&D programmes. As soon as the purchase was complete, we launched an extensive dedicated research programme dubbed DRACCAR, which comprises several projects covering six topics ranging from behaviour of the structure to the monitoring of marine megafauna. For the latter, the DRACCAR-MMERMAID project deploys a very innovative approach which brings together a large number of partners from academia, SMEs and large industrial groups. It is through projects such as this that the Institute takes on its full meaning. Several major changes were also introduced to strengthen the Institute's internal organisation. Ronan Stephan took up his role as the new Chairman in September, and Ludovic Noblet joined us as Development and Valorisation Director to take charge of and boost industrial transfer. This will buttress the bridge we are building between research and industry. Our team also expanded, while retaining its dynamic character and daily involvement in the projects we support.

Ronan Stephan: Herveline was appointed as Executive Director at the start of 2023, after previously occupying the position of Deputy Executive Director. The Institute has also been bolstered through the addition of four major new members: Iberdrola, Alliance Sorbonne Université, Océanide and Ecole centrale de Nantes. It is clear that the Institute's reputation has been growing over past years and, by 2023, France Energies Marines became perceived as a reference organisation at European level. The Institute is becoming truly established as a hub where industry, public authorities and research come together to hold discussions and set up projects. We strive to capitalise on this recognition to cement our ambitions for the offshore wind sector.

How do you see 2024?

Herveline Gaborieau: Some key deadlines are coming up, the most important from our perspective being the renewal of the Institute's agreement with the French State for 2025-2030. This comes against a relatively complex backdrop in which the offshore wind sector is in search of solutions to address the difficulties it faces. These difficulties highlight the necessity of R&D, especially in relation to offshore wind. This sector is developing in France and its place in the landscape can be carved out if it is given the necessary resources.

Ronan Stephan: The roll-out objectives are very ambitious at national level, and even more so at European level, however decision-making and financing are not keeping pace. There are also strong tensions in relation to raw materials, components, installation vessels, etc. There is therefore a real need for innovation, in particular in terms of farm architecture and turbine design, to breathe new life into the sector and guarantee electricity generation at an acceptable cost. Being at the crossroads between the different stakeholders, France Energies Marines is poised to play a pivotal role.

Herveline Gaborieau: 2024 is also the year of France's public debate on maritime spatial planning. What is clearly emerging is the need for further knowledge, in particular on the long term environmental and socio-economic effects of farms at the scale of each coastline. Studies into these effects are at the centre of the Institute's roadmap and we are developing tools to provide answers, especially through an ecosystem-based approach that we have been consolidating since 2015. Through this approach, we are able to assess the overall effects of farms, while integrating other human activities at sea.

How far do you expect the Institute to have progressed by 2030?

Herveline Gaborieau: I think that France Energies Marines has now begun to turn a corner to continue to carry forward a strong R&D activity for the sector by supporting its entire value chain. We are acquiring infrastructures such as the Fécamp met mast to provide the different stakeholders with the resources they need to test equipment and ensure it is reliable in representative conditions of those found at sea.

Ronan Stephan: We are well aware that the international targets for offshore wind for 2030 are extremely ambitious. Objectively speaking, we are not on track to meet them. We must provide evidence by becoming even more proactive in coordinating research and experimentation, including on topics that are slightly outside of our core areas of specialisation. We have the credibility to do so. It is also thanks to the quality of our partnerships that we are in a position to bring together and coordinate truly decisive actions for the sector.

Herveline Gaborieau: Today, we are structuring our partnerships with our long-standing members but also with other research institutes to build an overall response to put to the sector across all R&D challenges.

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01

IDENTITY

FRANCE ENERGIES MARINES

is the Institute for Energy Transition for offshore wind.

80+
staff

140+ partners
WORLDWIDE

A **public-private partnership**

supported by the France 2030 investment plan

4 sites
along the French coastline

Involvement in over
80 R&D projects
since 2012

Over €**10** million
annual budget

29 public and private members

Position

Vision and ambition

France Energies Marines is a research and innovation centre devoted to offshore wind energy with a recognised industrial, economic and societal impact in France and internationally. Its goal is to be the driving force behind a sector that creates value for local communities by:

- Consolidating reference standards and software to qualify wind resources and the operating conditions of future offshore wind farms and ensuring their technical and economic viability.
- Developing operational tools to ensure reliability and optimal design, and control operating and maintenance costs, at both turbine and farm level.
- Developing reference methods and tools to optimise the environmental and socio-economic integration of offshore wind farms.

Mission

Our mission at France Energies Marines is to resolve bottlenecks to the development of offshore wind energy through research and innovation. To do so, the Institute draws on cutting-edge R&D led by an 80-strong multidisciplinary team and one-of-a-kind infrastructures to propel innovation forward. It also brings together a broad network of academic experts and partners who work in close collaboration with its researchers.

Through its actions, France Energies Marines is helping France to become the leader in green hydrogen and renewable energies by 2030, one of the ten objectives set out by the French government as part of the France 2030 investment plan.

Challenges facing the offshore wind energy sector

Change of scale (increased power density and turbine capacity)

Strengthening of the **supply chain** and associated skills

Objectivization of **planning** and **impacts**

Improvement of system **reliability and design**, O&M **cost control**
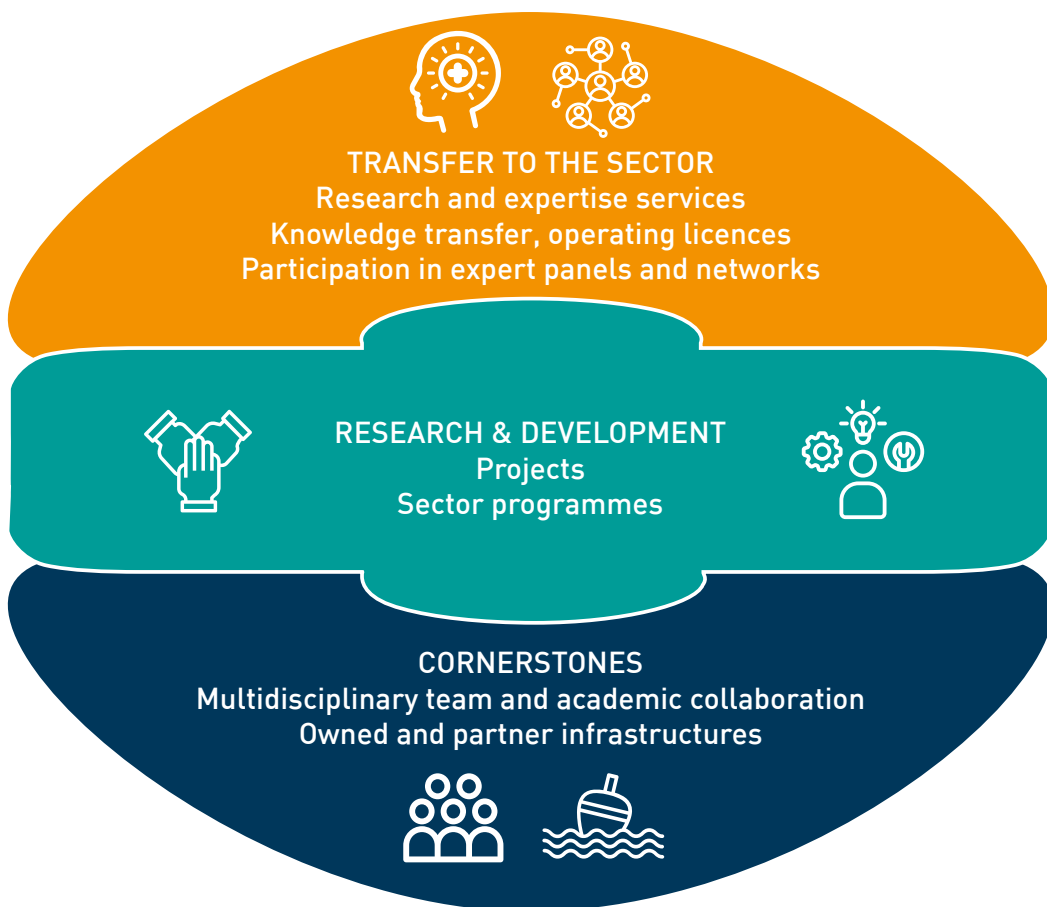
Economic viability of floating wind

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Activities

The Institute's activities are built on two corner-stones: a multidisciplinary team with invaluable expertise and high-level collaboration, and infrastructures, whether belonging to the Institute or to partner organisations, to carry out high added-value experimentation.

The R&D carried out by France Energies Marines takes the form of projects lasting between 18 and 42 months and long-term sector-focused programmes.

The outputs are intended to be transferred to offshore wind sector stakeholders. This transfer currently takes the form of research and expertise services, operating licences, know-how transfer and participation in expert committees and networks.

TRANSFER TO THE SECTOR
Research and expertise services
Knowledge transfer, operating licences
Participation in expert panels and networks

RESEARCH & DEVELOPMENT
Projects
Sector programmes

CORNERSTONES
Multidisciplinary team and academic collaboration
Owned and partner infrastructures

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Topics

Four complementary thematic programmes have been defined in our scientific and technical roadmap: site characterisation, systems design and monitoring, farm optimisation and environmental integration. The research and innovation led by the Institute across these four programmes focuses on the main issues—whether technological, environmental, economic or societal—related to the development of offshore wind energy.

Site characterisation

The purpose of this programme is to provide reliable data and tools to improve site selection and turbine design and to optimise offshore operations. The work conducted as part of this programme aims to minimise uncertainties over production estimates and design conditions, to develop systems for short-term wind and wave forecasting, and to characterise the interactions between coastal morphodynamics and wind farms. It includes the effects of climate change and increasing farm density.

Systems design and monitoring

The aim of this programme is to provide industry players with realistic, robust solutions to improve the design of their systems and ensure their reliability and integrity throughout their operational lifetime. To do so, it is crucial to develop numerical and experimental tools to precisely characterise the mechanical and hydrodynamic behaviour of moorings, foundations and power cables. The representativeness of the numerical models for the systems deployed during the operational phase must also be improved, through digital twins and in-service monitoring. This can only be achieved through the use of *in situ* data.

Farm optimisation

A wind farm is by no means simply an aggregation of production units; rather it should be considered as a whole entity, whose architecture and operating phase can be optimised to obtain the best cost-performance compromise. With this as a backdrop, this programme aims to provide stakeholders in the sector with tools to help them strike this optimal technico-economic balance. Another key element in this programme consists in tackling grid integration challenges by considering potential innovative solutions such as floating substations or power-to-X.

Environmental integration

Setting up a wind farm is liable to trigger environmental impacts and lead to socio-economic repercussions. This programme focuses on certain key ecosystem compartments, such as birds, marine mammals and fish, while taking a holistic approach. The aim is to develop tools and methods to measure, qualify, analyse, and predict the impacts of offshore farms, with a view to also contributing to maritime spatial planning.

SITE CHARACTERISATION

- Spatialisation of observations
- Characterisation of sea states
- Characterisation of wind at sea
- Climate change
- Hydrosedimentary processes

SYSTEMS DESIGN AND MONITORING

- Structure, mooring and electrical cable
- Hydrodynamical and structural coupling
- Digital twins and in-service monitoring
- Technological innovation

4 complementary

cross-cutting programmes

ENVIRONMENTAL INTEGRATION

- Effects on ecosystem compartments
- Scale change
- Tools for environmental integration

FARM OPTIMISATION

- Farm architecture
- Grid integration
- Installation, operation and maintenance

1

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3

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Governance

The Institute is built around a broad public-private partnership that brings together 18 shareholder members and 11 contributor members—all key French offshore wind sector participants—from industry, academic and scientific establishments, local authorities and competitive clusters. France Energies Marines is governed by decision-making bodies and consultation bodies which ensure that its orientations continue to be aligned with the needs of the sector.

In terms of decision-making, three bodies have been defined:
- The **General Assembly**, composed of all shareholder members, appoints the Institute's Chairman and guides its strategy and functioning,
- The **Board of Directors**, made up of 10 members elected among the Institute's shareholders, prompts and oversees the strategy's operational implementation,

- The **Executive Management**, appointed by the Board of Directors, which implements the strategy, submits proposals to the Board of Directors, oversees the implementation of the decisions made by the General Assembly and the Board of Directors, while handling the operational running of France Energies Marines.

In addition, two consultative bodies have been set up:
- The **Research & Development Committee**, which brings together all the Institute's members, ranks R&D topics by priority and examines the scientific merits of the multi-partner R&D projects set up by France Energies Marines,
- The **Science & Technology Committee**, composed of 8 independent international experts, issues an opinion on the Institute's scientific and technological programme and its materialisation via R&D projects. It also makes forward-looking recommendations on desired developments.

BOARD OF DIRECTORS - FULL MEMBERS

5 PUBLIC MEMBERS

ENSTA BRETAGNE	Ifremer	Nantes Université	Région BRETAGNE	UNICAEN UNIVERSITÉ CAEN NORMANDIE
Represented by **Bruno Gruselle**	Represented by **Jean-Marc Daniel**	Represented by **Franck Schoefs**	Represented by **Daniel Cueff**	Represented by **Lamri Adoui**

5 PRIVATE MEMBERS

EDF	INNOSEA An ABL Group Company	POLE MER BRETAGNE ATLANTIQUE	Shell	TotalEnergies
Represented by **Ève Dufossé**	Represented by **Hakim Mouslim**	Represented by **Philippe Monbet**	Represented by **Cédric Marande**	Represented by **Edmond Coche**

EXECUTIVE MANAGEMENT

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Herveline Gaborieau
Executive Director
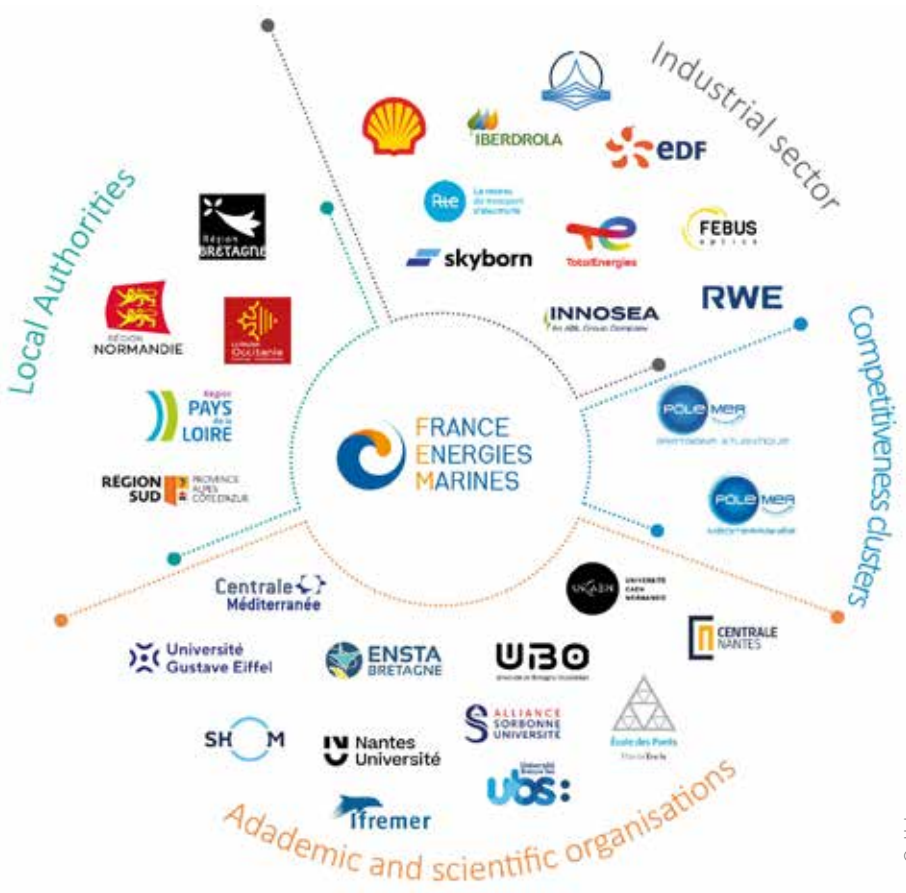*of France Energies Marines*

CHAIR

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Ronan Stephan
Chairman
of France Energies Marines

GENERAL ASSEMBLY - SHAREHOLDER AND CONTRIBUTOR MEMBERS

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Locations

Given its national vocation, France Energies Marines has always taken into consideration the specific characteristics of the different French coasts and the local stakeholders. Our proximity, which is therefore a major asset, is reflected in our strategic locations, with each site broadening its reach as the Institute grows. France Energies Marines is particularly eager to support the development of bottom-fixed and floating offshore wind farms, working closely with pilot and commercial projects.

Headquarters at the tip of Brittany

Ever since the creation of France Energies Marines in 2012, its headquarters have been based in Plouzané, near Brest. Shortly after, it moved to join the maritime cluster Pôle Mer Bretagne Atlantique and Technopôle Brest-Iroise in the Cap Océan building, the showcase building of Campus mondial de la mer. The proximity with these organisations and initiatives at the crossroads of collaboration between research and the marine and maritime industry reinforces synergies with the local ecosystem.

Atlantic office

France Energies Marines has had an Atlantic office since 2017. This office is located in Nantes, on the campus of the Ecole centrale, which fosters collaboration between researchers and businesses through complementary initiatives. Several PhD and post-doctoral students are also hosted by the Institute's partner laboratories in the Loire Valley.

Mediterranean office

Our Mediterranean office was set up in 2019 and is being developed by a multidisciplinary team based in Marseille, on the premises of the Ecole centrale Méditerranée. PhD and post-doctoral students are also hosted and co-supervised by partner laboratories in the SUD Provence-Alpes-Côte d'Azur and Occitanie regions. The partnership with the maritime cluster Pôle Mer Méditerranée also strengthens collaboration between researchers and businesses in the two regions.

Eastern Channel - North Sea office

Our Eastern Channel - North Sea office opened at the end of 2022 and is located on the premises of the Université Le Havre Normandie. Its vocation is to support the development of wind energy off the Normandy coast. This local presence will also be valuable in 2023 for the launch of a structured research programme to study the interactions between offshore wind energy and the marine environment, through the instrumentation of a met mast located off Fécamp.

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3 QUESTIONS for...
Ludovic Noblet

Development and Valorisation Director
France Energies Marines

What is the context surrounding the development of the Institute's new strategic plan?

It is connected to the renewal of the Institute's funding agreement through a 2025-2030 strategic roadmap agreed with the French State. The French Government has set out a clear trajectory for the 15 Institutes for Energy Transition and Technological Research with regard to their funding model, which must comply with the following breakdown: 1/3 private sector investment, 1/3 match funding through the France 2030 investment plan, and 1/3 internally generated funds. The latter category includes revenue generated by the industrial transfer of know-how, tools and/or technologies developed through our R&D programmes. Ultimately, the path we are being asked to take involves developing our innovation capacities, beyond the scientific capacities that are already recognised. This is a key point for the development of France Energies Marines and it has guided much of our thinking behind the new strategic plan.

How did you go about developing the plan?

We focused on the challenges facing the offshore wind energy sector. Whether environmental, socio-economic, industrial or technological, they are central to de-risking the implementation of France's ambitions and reaching its target: an installed capacity of 18 GW by 2035 and 45 GW by 2050. More than ever before, those working in this sector will need knowledge, together with qualified data obtained in operational conditions, and the necessary tools to work with this data. The imperatives of scale—national, European, and global—call for significant efforts to accelerate the development of standards. Cost control, particularly costs associated with maintenance in operational condition, is a major challenge for the economic viability of floating wind. Together with our investors, we have adjusted France Energies Marines' vision and ambitions for 2030. Through this effort, we have clarified our mission and highlighted our differentiating features, which form the backbone of our new strategic plan.

What are the plan's key components?

The document outlines an organisation for the Institute which will allow us to work even more closely with the sector, and in particular with SMEs and intermediate-sized enterprises which are an essential component due to local content requirements and the economic development potential of offshore wind. While cutting-edge R&D continues to be our core focus, thanks to our a multidisciplinary team and offshore infrastructures, we will be increasing our capacity to support innovation. This means enhancing our ability to understand the market and its dynamics. Digital tools, for instance, are set to play an increasingly important role. The Institute has developed solid experience in digital twins and modelling. We will therefore be focusing on the transfer of software tools for in-service monitoring applied to the control of operating and maintenance costs and on ecosystem modelling in relation to cumulative impacts. To do so, we will need additional engineering resources. Finally, we plan to strengthen our ability to support companies' innovation needs by enabling them to carry out tests in operational conditions using our offshore infrastructures. Access to such facilities is often a barrier to market entry for start-ups, SMEs and intermediate-sized enterprises. We intend to remedy this, in particular by fostering synergies with other players such as the OPEN-C Foundation.

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HIGHLIGHTS OF
2023

Systems design & monitoring |
March
Deployment of a demonstrator in the Mediterranean to study nylon moorings in representative conditions, on a reduced scale, of the average dynamic forces generated by a floating wind turbine.
MONAMOOR and ABIOP+ projects

Institute |
January
Appointment of Herveline Gaborieau, former Deputy Executive Director, as the new Executive Director of the Institute, taking over from Yann-Hervé De Roeck who held the position since the Institute was created in 2012.

Institute |
April
Iberdrola France, an international energy company, becomes a member of the Institute.

Institute I
April to June

The Institute is present at 4 key sector events:
- WindEurope in Copenhagen
- FOWT in Nantes
- European Maritime Days in Brest
- Seanergy in Paris

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Institute I
May

Launch of DRACCAR, the first French offshore research platform dedicated to offshore wind energy, coupled with an innovative €8.2 million R&D programme.

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Systems design & monitoring I
May

Publication of a recommendation report on the in-service monitoring of dynamic power cables used in floating wind farms.
DYNAMO project

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Environmental integration I
June to July

Release of 3 new bulletins on the potential effects of the electromagnetic fields produced by power cables, the metals released by galvanic anodes, and the risk of entanglement in wind farms for marine megafauna.
COME3T project

© COME3T

Institute I
September

Appointment of Ronan Stephan as the new Chairman of France Energies Marines, as successor to Jean-Philippe Pagot.

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Institute I
September

Participation in European Researchers' Night, with events on the theme of energy in the future looking towards 2050.

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Institute |
September

Centrale Nantes, a leading international engineering school, becomes a shareholder in France Energies Marines.

Institute |
November

Alliance Sorbonne Université, a leading international university in the field of ocean sciences, and Océanide, an SME specialising in prototyping and test campaigns, become members of the Institute.

Site characterisation |
October

Public webinar to present new tools developed to improve turbine design by better integrating breaking wave loads.
DIMPACT project

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Environmental integration |
December
Workshop in Nantes on acoustic telemetry, with a theoretical part followed by a discussion on the use of this technology in future research projects. *FISHOWF project*

Farm optimisation |
November
Launch of the European HYDEA project to accelerate the hydrogen transition in Atlantic area ports.

Institute |
December
5th France Energies Marines Science and Technology Tribune at the renewable energy forum EnerGaïa in Montpellier.

2023 press review

10 January

Herveline Gaborieau, new Executive Director of France Energies Marines.

10 articles

12 January

How do fish and crustaceans visit offshore wind farms?

2 articles

31 January

Characterising offshore wind turbulence to increase the profitability of future Mediterranean wind farms.

5 articles

20 February

Mooring of floating wind turbines: towards a reliable solution with polyamide lines.

5 articles

15 March

OPTILE: decarbonising the supply of electricity to island grids.

6 articles

21 April

Iberdrola France joins France Energies Marines.

2 articles

09 May

Launch of DRACCAR, the first French offshore research platform dedicated to offshore wind energy, coupled with an Innovative €8.2 million R&D programme

11 articles & 2 reports

05 September

Ronan Stephan becomes the new Chairman of France Energies Marines.

11 articles

12 September

Offshore wind - France Energies Marines is launching a €13M investment in an ambitious research and innovation programme

7 articles

10 October

Floating Offshore Wind - New tools to improve turbine design by better integrating breaking wave loads.

4 articles

20 & 21 November

Sorbonne Université and Océanide join France Energies Marines.

1 article

07 December

France Energies Marines Science & Technology Tribune: spotlight on R&D results related to the challenges of offshore wind energy.

1 article & 1 report

03

EXPERTISE

France Energies Marines sets itself apart through its cutting-edge, multidisciplinary expertise in offshore wind energy. With a team of over 70 researchers, engineers and technicians together with a capacity to mobilise leading partners in France and internationally, it provides support for the sector via a holistic approach.

A multidisciplinary team

A team 100% dedicated to research and innovation

France Energies Marines boasts France's largest team of scientists entirely devoted to offshore wind energy research and innovation. Its multidisciplinary composition and cross-cutting approach are valuable assets thanks to which it is able to address R&D topics in a holistic and pragmatic manner. Between 2019—the year in which France Energies Marines was granted status as an Institute for Energy Transition—and 2023, its workforce increased by 100%, from 40 to 80 employees. While support roles consequently expanded, scientists still make up the vast majority of the staff. They are divided into four thematic programmes: site characterisation, systems design and monitoring, farm optimisation and environmental integration. 75% of employees are on permanent contracts, enabling the Institute to maintain its expertise on advanced scientific topics.

A strong professional equality policy

The Institute has a policy of professional equality and equal pay for men and women, which is soon to be formalised by the signing of a specific agreement. This agreement covers recruitment, effective pay, training, professional promotion and career development conditions, as well as the work-life balance. In 2023, France Energies Marines had a professional equality index of 89/100, compared with the national average of 88/100. This index is calculated out of 100 on the basis of four indicators: the pay gap, the gap in individual pay rises between women and men, the percentage of employees granted a pay rise upon return from maternity leave, and the distribution of women and men for the ten highest salaries.
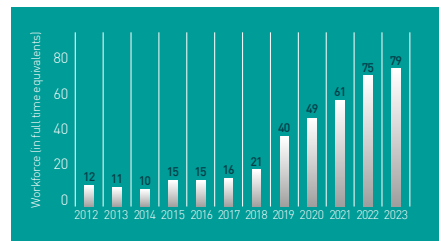
I Evolution of the number of employees

Site characterisation

The site characterisation programme involves around twenty people, composed of 41% researchers, 27% engineers, 9% technicians and 23% PhD students. Their main disciplines are meteorology, physical oceanography and geology. This team combines high-level numerical approaches with flume tank experiments and at-sea measurements. It is particularly renowned for its work on the detailed assessment of wind turbulence intensity, and the realistic evaluation of loadings on structures due to breaking waves.

Marine Operations Unit

Created in autumn 2023, the Marine Operations Unit is composed of an operational, cross-cutting team of four people in charge of coordinating France Energies Marines' offshore activities. Its missions focus on three key aspects:

- Specification of measurement systems, then mechanical, electrical and IT integration according to the specificities of the deployment site.
- Management of offshore operations, applying good HSE practices.
- Monitoring of the Institute's offshore research infrastructures.

I Site characterisation team

Systems and farms

Around twenty people are involved in the systems design and monitoring and farm optimisation programme. The team is made up of 41% researchers, 45% engineers and 14% PhD students. It covers a broad range of disciplines: structural and fluid mechanics, applied mathematics, geotechnics, electrical engineering, etc. The work carried out combines numerical modelling, laboratory testing and offshore experimentation. Over time, this team has developed unique expertise in digital twins of floating wind turbines, in-service monitoring of dynamic subsea cables, and the behaviour of polyamide moorings. More recently, it has been working on emerging issues such as direct current floating substations, heavy maintenance at sea, and hydrogen production from offshore wind turbines.

I *Systems and farms team*

Environmental integration

The environmental integration programme involves 25 people, composed of 60% researchers, 32% engineers and 8% PhD students. The team includes experts in each compartment of the marine environment—benthos, fish, mammals and birds—as well as socio-economic experts and specialists in socio-ecosystem modelling. It boasts recognised know-how in species monitoring at different temporal and spatial scales, in particular in relation to data processing. Given the topics it addresses, this team also carries out scientific outreach activities geared towards the general public.

Socio-ecosystem Approach Unit

This unit develops management tools for those working in the sector, to provide a holistic vision of the marine ecosystems in which offshore farms are set up. Trophic modelling is used to assess the cumulative impacts of different offshore activities, before and after the installation of infrastructures. It can be coupled with other socio-ecosystem-based tools or approaches to create a balanced vision through the assessment of environmental and socio-economic impacts of wind farms during the different phases of their life cycle.

I Environmental integration team

Support roles

Support roles are carried out at the Institute by around fifteen people with a wide range of profiles. This label covers very different components with a shared mission: to contribute to the smooth running and the development of the Institute, while supporting the scientific teams on a daily basis.

- The **Scientific Management** coordinates the Institute's scientific activities, leads the project generation and selection process, and communicates on R&D work.

- The **Development and Valorisation** department develops partnerships, seeks new members, leads the Institute's commercial strategy and manages the various digital infrastructures.
- The **Administration, Finance and Legal** department assists staff with administrative management, draws up the necessary contractual documents, ensures sound financial management, monitors R&D activities and reports to government services and members of France Energies Marines.

I Support roles team

3 QUESTIONS for...
Anne-Sophie Garo

Human Resources Manager
France Energies Marines

What changes were there to the Institute's team in 2023?

This year, the team has again grown significantly, with a 27% employee growth rate, increasing from 62 at the end of 2022 to 80 by the end of 2023. The team is composed of an increasing proportion of permanent staff, with the share of permanent contracts rising from 50% to 76% over a two-year period. This trend reflects the management team's strong desire to retain the wide diversity of profiles recruited in order to consolidate the Institute's expertise and build on it to promote a cross-cutting approach. The Institute continues to enhance its internal organisation with the creation of the Marine Operations Unit to organise offshore experimentation in the best possible conditions. Other units may be created in the future. 2023 also saw leadership changes, both within management and the board. Herveline Gaborieau, formerly Deputy Executive Director, became the new Executive Director and Ronan Stephan was appointed as the new Chairman. The Institute's Development and Valorisation activity has also been strengthened with the recruitment of Ludovic Noblet to head up this key department.

Are the regional offices also reflecting this growth?

Although the majority of the workforce is still based at the Institute's headquarters in Brest, the regional offices have also seen a successful roll-out and are continuing to develop. In Nantes, staff numbers in the Atlantic office have doubled, with a ten-strong team today. Seven people are already based at the Mediterranean office in Marseille, which is set to expand in 2024. Three staff members are based at the very recent Eastern Channel - North Sea office in Le Havre, with additional staff set to join them soon.

How would you describe the current team?

We are lucky to have a very diverse range of profiles from both academia and industry, combining to form a passionate, multidisciplinary team. This is a real asset because it fosters dialogue between employees who may have diverging visions, ideas or simply different experiences. The Institute is enriched through these discussions. When recruiting, we also strive to select candidates who fit with this mindset, in order to foster these dynamics which create real added value.

A network of experts and partners

The Science & Technology Committee

This Committee is made up of independent experts whose mission is to critically review the France Energies Marines roadmap and put forward recommendations to improve the R&D projects led by the Institute. The experts are chosen for their experience in the sector and/or in applied R&D projects. They work for prestigious institutes in different countries and are renowned in their field of expertise. They thus have good insight into how our work meets expectations within the offshore wind sector.

SITE CHARACTERISATION

Deborah Greaves
Professor of ocean engineering
United Kingdom
UNIVERSITY OF PLYMOUTH

Xiaoli Guo Larsén
Researcher in resource assessment and meteorology
Denmark
DTU

SYSTEMS DESIGN AND MONITORING

FARM OPTIMISATION

Erin Bachynski-Poli
Professor in the design and analysis of energy recovery systems
Norway
NTNU

Emmanuel Branlard
Researcher in multiphysics modelling of wind turbines
United States

Hannele Holttinen
Expert in energy systems integration
Finland

Thomas Sauder
Researcher in cyber-physical testing and applications to marine technology
Norway
SINTEF

Science & Technology Committee

ENVIRONMENTAL INTEGRATION

Claire Haggett
Senior lecturer in environmental sociology
United Kingdom
THE UNIVERSITY of EDINBURGH

Lenaïg Hemery
Benthic ecologist
United States
Pacific Northwest NATIONAL LABORATORY

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A network of key experts and partners

France Energies Marines brings together a national network of experts recognised by their peers. These scientists are part of research teams belonging to universities, engineering schools, public establishments and SMEs. The Institute also fosters fruitful collaboration with various key French and international R&D players.

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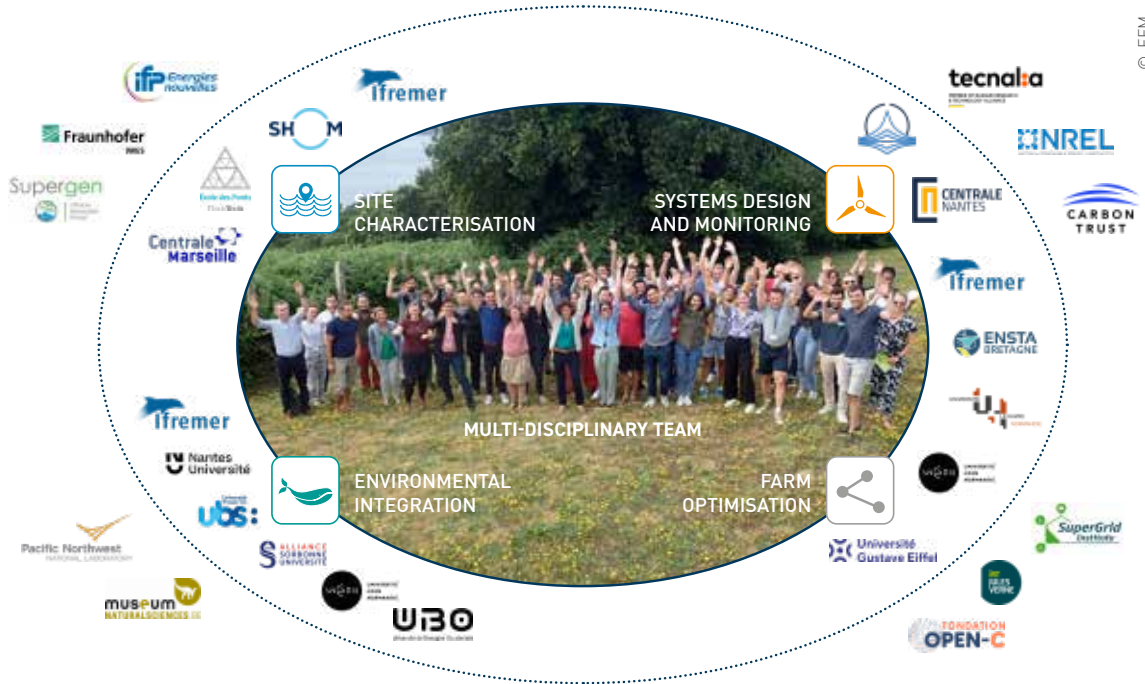
RESEARCH INFRASTRUCTURES

To carry out its research and innovation activities, France Energies Marines draws on its network of research infrastructures. Its offshore observatories showcase the Institute's ongoing commitment to supporting the development of offshore wind energy. Fully aligned with the national strategy, they play a pivotal role in planning and risk management. In parallel, the Institute is developing offshore platforms to test technological building blocks and a first-rate digital infrastructure: the RESCORE resource centre. These different research infrastructures are highly complementary to the resources of academic laboratories.

Offshore observatories

The Institute's network of offshore observatories has several objectives:
- To develop reliable real-time monitoring solutions and protocols adapted to the offshore environment,
- To observe interactions between offshore wind energy and the environment at the scale of the coastline, in order to assess the effects on ecosystems, quantify the physical parameters and their spatio-temporal variations, optimise system design and adapt monitoring protocols,
- To provide qualified data and processing tools,
- To support decision-making about the deployment of future farms.

The Fécamp met mast

In 2023, France Energies Marines purchased the met mast located in the vicinity of the Fécamp offshore wind farm. This mast will be a major building block in the national offshore observation network developed by the Institute, and is the first French offshore research platform dedicated to offshore wind energy. Installed on a gravity foundation, the mast reaches a height of 40 metres above sea level. It is particularly well suited to the deployment of innovative instruments, with several already installed:

- A MOTUS radio telemetry station, camera traps and microphones to monitor flying wildlife,
- An acoustic telemetry network to monitor fish and crustaceans,
- Anemometers, a weather station and a profiling lidar to measure wind parameters,
- Accelerometers and a stereo-video system to study the hydrodynamic forces of waves on the structure.

Some of the data collected will be integrated in the RESCORE platform and will be available for consultation subject to certain conditions.

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Sonic anemometer

Weather station

Accelerometers

Microphones

Cup anemometer

Camera trap

Profiling lidar

Motus radio telemetry station

Accelerometers

Stereo-video system

© FEM, Yohann Boutin

I Instrumentation already in place on the met mast

A sentinel lighthouse for giant waves

The Jument lighthouse is located off the coast of Ushant Island in an area that is representative of the bathymetry of offshore wind farm sites. Since 2017, it has been used as a full-scale experimental device to carry out measurements directly in the field. Equipped with a stereo-video camera system, pressure sensors and accelerometers, it records data on the breaking and impact of extreme waves. With this device, a giant breaking wave more than 24 m high was observed and its impact measured. This information is essential to optimise the design models, and therefore the cost, of future offshore wind turbines, while guaranteeing their storm-resistance.

A lidar to measure wind turbulence at sea

A profiling lidar was deployed on Planier Island for 12 months to fill the gaps in wind and turbulence measurements in the Gulf of Lion. This completely flat island offers conditions that are representative of the offshore environment, similar to those of the future pilot farm sites in the Mediterranean.

© FEM

I WindCube v2.1 profiling lidar deployed on Planier Island

Instrumented buoys to study biofouling

The Institute has several instrumented buoys deployed in the Atlantic and the Mediterranean, as close as possible to future offshore wind farms. Equipped with biofouling monitoring devices, these buoys can be used to study the biofouling of underwater structures by marine organisms. Using the data collected, the biofouling can be characterised and quantified for different environmental conditions and different depths, in order to better understand its variability and clarify its effects on structures. The information provided is particularly useful for the design, deployment and operation of floating wind turbines.

An acoustic telemetry network to monitor fish and crustaceans

To study the effects of offshore wind farms on fish populations, some forty acoustic telemetry receivers have been deployed at offshore wind farm sites in the Channel, Atlantic and Mediterranean. Meanwhile, several hundred fish and crustaceans were fitted with acoustic transmitters. With this technology, the movements of these marine organisms are recorded, providing information on their presence within the farms.

© FEM

I Maintenance operation on the APPEAL buoy in the Atlantic

Offshore platforms to test technological building blocks

Instrumented demonstrator to study moorings

The MONABIOP demonstrator was deployed in February in the Mediterranean to study the behaviour of polyamide moorings in real conditions. Designed as a 7-tonne buoy fitted with a semi-tensioned hybrid chain and nylon mooring and several tension and elongation sensors, MONABIOP offers a realistic representation of the average dynamic forces generated by a floating wind turbine. Thanks to this configuration, the performance of polyamide moorings can be precisely assessed, opening the door to more efficient and sustainable solutions for the development of floating wind energy.

I Detailed view of the mooring of the MONABIOP demonstrator

© FEM

© FEM

I MONABIOP demonstrator deployed at sea

Offshore observatories

Offshore platforms to test technological building blocks

Fécamp met mast
Multi-instrumented

Jument lighthouse
Extreme waves

APPEAL buoy
Biofouling

MONABIOP demonstrator
Mooring lines

((•)) **Acoustic telemetry networks (7 sites)**
Fish monitoring

MEMOFLOW buoy
Biofouling, waves

Profiling lidar
Wind, turbulence

I Diagram identifying all the offshore observatories and platforms

© FEM

Digital infrastructure

French resource centre RESCORE

RESCORE is an online resource centre offering pooled access to useful information for the development of the offshore renewable energy sector in France. Initiated and operated by France Energies Marines, the platform currently focuses on the results of the Institute's R&D projects, but is gradually opening up to data from various stakeholders in the field, thereby enabling shared access to relevant information for the development of France's offshore renewable energy sector.

RESCORE takes the form of a user-friendly web portal featuring an intuitive mapping tool via which users can conduct searches and view data based on different criteria, such as the type of technology or the maritime region. RESCORE is interoperable with the main French and foreign resource centres, which promotes knowledge exchange and collective progress for the sector.

The RESCORE platform displays metadata relating to a vast array of documents, maps, time series and spatial measurements. Thanks to this transparency, all stakeholders in this sector have access to the relevant information, while complying with the confidentiality and data use requirements defined by the data owners.

RESCORE is targeted towards a wide array of stakeholders, including farm operators, technology developers, consultancies, national and regional decision-makers and academic researchers. Users can interact with the platform in two main ways: efficiently consulting the available data and contributing by sharing their own data, leading to enhanced visibility and financial opportunities.

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I Example display of the RESCORE interface

© FEM

3 QUESTIONS for...
Jean-Sébastien Verjut

Mooring Systems and Marine Operations
Research Engineer
France Energies Marines

What is the purpose of the MONABIOP demonstrator?

This demonstrator is a significant investment for France Energies Marines and constitutes a valuable platform for offshore testing of mooring line components and in-service monitoring instruments for polyamide moorings. It takes the form of a 7-tonne buoy fitted with a semi-tensioned hybrid chain and nylon mooring and several tension and elongation sensors. It is representative, on a reduced scale, of the average dynamic forces generated by a floating wind turbine. It is also designed to study the colonisation kinetics of polyamide lines by living organisms (algae, molluscs, etc.) and the influence of elongation on this process.

In what way is the demonstrator innovative?

Over and above the use of nylon ropes for its mooring system, its innovative nature lies in an advanced in-service monitoring system, which not only measures the tension and elongation of the mooring lines, but is also capable of validating and qualifying new sensors. This system offers redundancy with two tension sensors on each line fitted with polyamide segments. One of the most noteworthy advances is the innovative elongation sensors developed by Ifremer. Their development was particularly complex, requiring the creation of special attachment systems to measure elongation on the mooring lines subject to slippage. Thanks to wire displacement transducers, accurate measurements were obtained, even at high tension levels. The demonstrator has also been used to test another innovative elongation sensor technology based on the transmission and reception of ultrasound. The rope elongation measurements recorded by this sensor, installed on one of the mooring lines, were validated by comparison with the filament elongation sensor. Finally, a third type of sensor, still at the prototype stage, is located inside nylon ropes and measures the pressure between the strands when the rope is taut.

What are the main results obtained so far?

The initial results are promising and pave the way for significant advances in the design and operation of future floating wind farms. They offer a better understanding of the behaviour and degradation factors of nylon ropes, and the development of reliable monitoring tools. The tests successfully validated the possibility of using innovative elongation and tension sensors in offshore conditions, which is a key milestone in improving the reliability of measurements in the marine environment.

The results of the numerical simulations are very encouraging as they confirm the relevance of the 1D behaviour law previously established for nylon ropes (POLYAMOOR research project, 2017-2020). Comparison of the tension and elongation measurements with the results obtained using a model developed by our team showed a very satisfactory correlation. These advances will play a crucial role in the reliability and durability of synthetic moorings for future floating wind farms.

03

R&D PROJECTS

As an interface between the private sector and public bodies, France Energies Marines pinpoints the R&D needs of the offshore wind sector, and responds to these needs by working with top-class academic, industrial and institutional experts. Since its creation, the Institute has provided scientific input to over 80 R&D projects, the majority of which were set up and managed by our team.

Types of projects led by the Institute

Projects led by France Energies Marines

The projects led by the Institute are initiated based on the needs expressed by its industrial members, then set up and carried out with constant vigilance as to the quality and applicability of the results obtained. Every year, five new projects are launched following a tried-and-tested selection process promoting scientific excellence, as detailed in the following pages.

The projects resulting from the Institute's annual R&D consolidation process can be carried out very openly, or in a more restricted manner requiring much greater confidentiality. They are supported by the France 2030 investment plan and various local authorities, as long as they secure funding from the industrial sector.

National projects

The Institute also takes part in collaborative projects mainly involving French stakeholders in the sector, particularly innovative SMEs. These are relatively select consortia including both private and public sectors. This type of project receives financial support from national schemes such as ADEME's calls for research projects.

European projects

In order to extend its international reach, the Institute takes part in European projects that bring together a large number of public and private partners from different countries that are relatively advanced in the development of offshore renewable energies. These projects are funded by European Union programmes such as Interreg and Horizon Europe.

Overview of achievements in 2023

The 30 collaborative projects in progress or completed in 2023 come under one or more of the Institute's four thematic programmes: site characterisation, systems design and monitoring, farm optimisation and environmental integration. 80% are set-up by France Energies Marines, 15% are supported by ADEME and 5% are funded by the European Union. They represent a total budget of €63 million and combined they involve nearly 105 partners.

Selection of the Institute's projects

❶ 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 working groups to determine the priority focal issues.

- For "restricted" projects, the topics are directly defined with industrial members of France Energies Marines, with support from a restricted circle of partner teams.

❷ Pre-proposals

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 Science & Technology 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 of Directors selects the most promising pre-proposals.
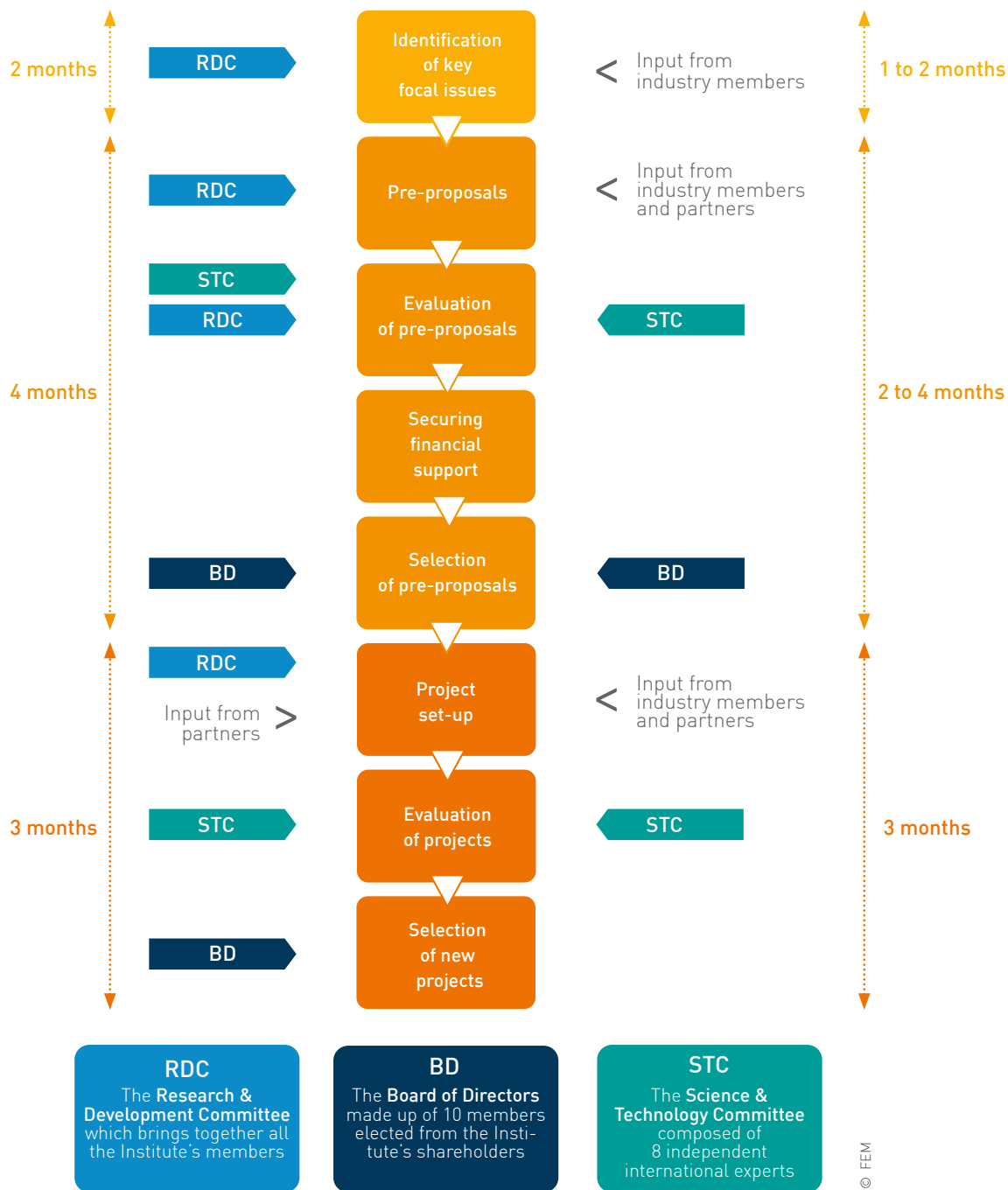
- For "restricted" projects, the pre-proposals are evaluated by the Science & Technology Committee and the Institute's management team. The funding plan is drawn up by the project partners and France Energies Marines. The Board of Directors then selects the most relevant pre-proposals.

❸ Projects 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 Science & Technology Committee. Taking into account the different appraisals, the Board of Directors validates the new projects to be launched.

"OPEN" PROJECTS

"RESTRICTED" PROJECTS

2 months	RDC	**Identification of key focal issues**
	RDC	**Pre-proposals**
	STC / RDC	**Evaluation of pre-proposals**
4 months		**Securing financial support**
	BD	**Selection of pre-proposals**
	RDC / Input from partners >	**Project set-up**
3 months	STC	**Evaluation of projects**
	BD	**Selection of new projects**

< Input from industry members — 1 to 2 months

< Input from industry members and partners

STC — 2 to 4 months

BD

< Input from industry members and partners

STC — 3 months

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 **Science & Technology Committee** composed of 8 independent international experts

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R&D PROJECTS

Site characterisation

Climate change impact on offshore wind

Duration: 18 months | **Launched:** 2023

Objective:
› To provide the French offshore wind sector stakeholders with different appropriate indicators to assess the expected evolution over the next few decades of wind resources, associated production and design conditions.
› To assess uncertainties of current approaches and reduce risk of conservatism, leading to reduced costs for renewable energies and better business plans for developers.

Scientific and technical content:
Literature, trends and physical mechanisms
› Literature review about trends and associated uncertainties.
› Identification of physical mechanisms behind these trends and link to the offshore wind sector.
› Impact of climate change on resource and yield.

Comparisons between regional climate models, long-term measurements and state-of-the-art reanalyses
› Spatial validation of the climate models, at the different places of interest for the development of offshore wind farms.
› Production of offshore wind-specific metrics and statistics for different horizons, but also continuously.
› Impact of climate change on design.

Comparisons between climate models, long-term measurements and recent reanalyses for waves and water levels
› Development of statistics and indicators for the evolution of distributions.
› Characterisation of the evolution of extreme occurrences and intensities.
› Estimation of the fatigue on the turbine tower according to the evolution of the wind distributions and the sea levels.
› Characterisation of the impact on the coastline for the cable landing and the onshore grid connection.

2023 achievements:
› Project launch in October and initiation of various scheduled activities.

Partners:
This project is led by RTE and France Energies Marines.

Total project budget: €725K

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I Impact of climate change on offshore wind

CASSIOWPE

Characterising the atmosphere and sea surface interactions for the deployment of offshore wind in the Gulf of Lion

Duration: 36 months | **Launched:** 2020 | **Completed:** 2023

Objective:
› To better characterise weather and ocean conditions in the Gulf of Lion to support the deployment of floating wind farms in the Mediterranean.

Achievements throughout the project:
› Compilation of existing *in situ* measurements, covering wind and sea states.
› Development of a coupled ocean-wave-atmosphere modelling chain to assess the impact of air-sea interaction on the wind resource.
› Creation of database comprising one year of wind, wave and current data generated using this coupled simulation.

2023 dissemination:
› Presentation:
  • Daudin C. (2023) Caractérisation de sites - Quels sont les enjeux pour la conception, le suivi et la maintenance des parcs éoliens flottants ? Tribune scientifique et technologique de France Energies Marines, Montpellier, France, 14/12/2023

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 France 2030 investment plan.
It also receives funding from the SUD Provence-Alpes-Côte d'Azur region and from the maritime cluster Pôle Mer Méditerranée.
This project is approved by the maritime cluster Pôle Mer Méditerranée.

I Characterisation of interactions between the atmosphere and the sea surface

DIMPACT

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

Duration: 40 months | **Launched:** 2020 | **Completed:** 2023

Objective:
› To develop new tools to improve the design of floating offshore wind turbines by better integrating loads due to wave breaking.

Achievements throughout the project:
› Study of the geometric and kinematic properties of breaking waves using numerical simulations and tank experiments.
› Wave flume tests using an instrumented cylinder representative of a spar turbine to reproduce the movements and inclinations typical of a floating wind turbine.
› Establishment of a relationship between the properties of breaking waves and the loads exerted on the cylinder in order to assess the loads induced by breaking waves in any sea state.
› Development and validation of an engineering formula specific to floating wind turbines, taking into account the movement and inclination of the turbine subjected to loads induced by extreme waves.
› Development of a solution for estimating the loads induced by equivalent non-linear waves, based on the properties of linear waves.
› Development of an engineering method to take account of the slamming force on a floating wind turbine, then integration into the codes of the DIEGO and OpenFAST tools.

2023 dissemination:
› Publications:
  • Batlle Martin M., *et al.* (2023) Deep water focused breaking wave loads on a fixed cylinder. *Coastal Engineering*, Vol. 186, 104397
  • Lucero F., *et al.* (2023) Improving WAVEWATCH III hindcasts with machine learning. *Coastal Engineering*, Vol. 185, 104381
  • Renaud P., *et al.* (2023) Semi-analytical load models describing the progressive immersion of a fixed vertical cylinder in a breaking wave. *Ocean Engineering*, Vol. 276, 114116
  • Renaud P., *et al.* (2023) Semi-analytical load models accounting for the tilt and motion of a cylinder impacted by a plunging breaking wave. *Proceedings of the ASME 42nd International Conference on Ocean, Offshore and Arctic Engineering*, Vol. 2, V002T02A021
› Presentations:
  • Hulin F., *et al.* (2023) Experimental investigation of parameters influencing hydrodynamic loads generated by breaking wave impacts on floating offshore wind turbines. International Workshop on Water Waves and Floating Bodies, Ann Arbor, Etats-Unis, 07/05/2023 – 10/05/2023
  • Renaud P., *et al.* (2023) Semi-analytical load models accounting for the tilt and motion of a cylinder impacted by a plunging breaking wave. 42nd International Conference on Ocean, Offshore & Arctic Engineering, Melbourne, Australie, 11/06/2023 - 16/06/2023
› Posters:
  • Renaud P., *et al.* (2023) Semi analytical load models describing the progressive immersion of a fixed vertical cylinder in a breaking wave. EERA DeepWind Conference, Trondheim, Norway, 18/01/2023 - 20/01/2023
  • Batlle Martin M., *et al.* (2023) Numerical investigation of breaking focused wave-induced loads on floating offshore wind turbines EERA DeepWind Conference, Trondheim, Norway, 18/01/2023 - 20/01/2023

› Event:
  • Organisation of a webinar, held on 18 October and attended by 74 participants, to present the project results.

Partners:

This project is led by France Energies Marines.

Total project budget: €2,600K

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 France 2030 investment plan.
It also receives funding from the Brittany and Réunion regions.
This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.

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I Wave flume tests using a model simulating a floating wind turbine

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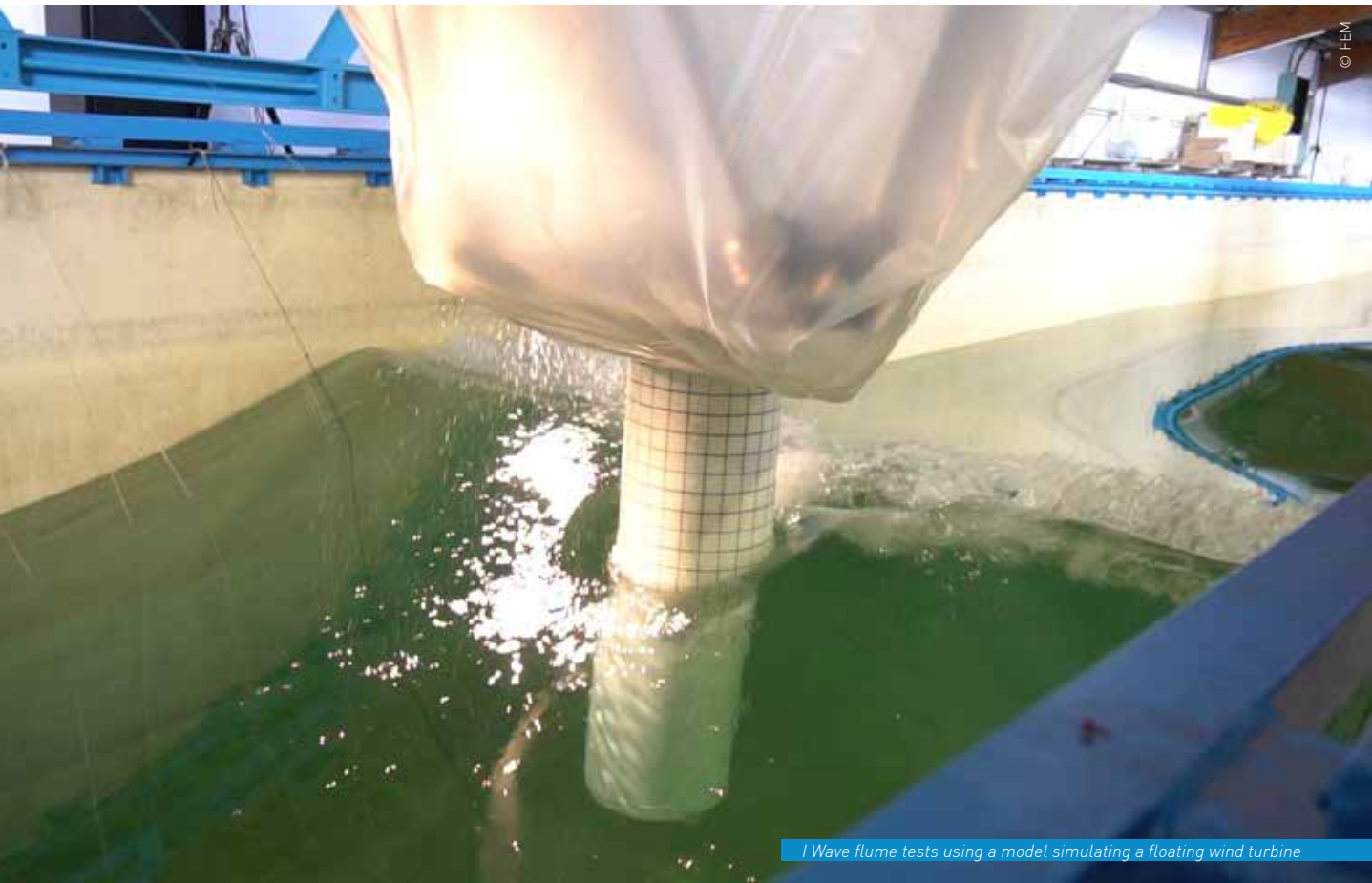
Modelling of underwater dunes: local and large-scale evolutions in an offshore wind context

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

Objectives:
› 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 an underwater dune field.
› Physical modelling of underwater dunes subjected to complex hydrodynamic forcings.
› Pre-study of dune ecological resiliency.

2023 achievements:
› Implementation and validation of models for high-resolution simulation of flows and sediment movements at the foot of wind turbines, as well as the movement of sand dunes off the coast of Dunkirk.
› Integration of wind turbine structures, foundations, and subsea cables into these models in order to assess their impact on dune movements.

2023 dissemination:
› Publications:
- Le Bot S., *et al*. (2023) Marine dune morphodynamics and sediment fluxes (off Dunkirk, France). Spatio-temporal variability and relations with hydrodynamic forcings. Proceedings of the 7th Marine and River Dune Dynamics Conference Series, Vol. 7, pp. 155-162
- Robert A., *et al*. (2023) Dynamic of the benthic ecosystem of bedform areas assessed via structural diversity, functional diversity and isotopic diversity. Proceedings of the 7th Marine and River Dune Dynamics Conference Series, Vol. 7, p 263-270
› Presentations:
- Durand N., *et al*. (2023) Understanding marine dune dynamics in a shallow shelf sea using sediment mobility indices. 7th Marine and River Dune Dynamics Conference, Rennes, France, 03/04/2023 - 05/04/2023
- Durand N., *et al*. (2023) GAIA can model large marine dunes: results from a sensitivity study in the southern North Sea. 21th TELEMAC User Conference, Karlsruhe, Allemagne, 11/10/2023 – 13/10/2023
- Gilletta A., *et al*. (2023) Hydrodynamic simulations of flow around a pile using turbulence-resolving models. 7th Marine and River Dune Dynamics Conference, Rennes, France, 03/04/2023 - 05/04/2023
- Morvan A., *et al*. (2023) Potential thermal impact of wind farms within a dynamic seabed. 7th Marine and River Dune Dynamics Conference, Rennes, France, 03/04/2023 - 05/04/2023
› Posters:
- Nexer M. (2023) How to study marine dunes in an offshore windfarm context. 7th Marine and River Dune Dynamics Conference, Rennes, France, 03/04/2023 - 05/04/2023
- Nicolas M. (2023) Estimation of marine dunes migration through sediment flux calculation and three-dimensional numerical modelling. 7th Marine and River Dune Dynamics Conference, Rennes, France, 03/04/2023 - 05/04/2023

Partners:

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

I Wave flume tests to study the dynamics of underwater dunes

OROWSHI

Offshore wind turbine design including joint wind-wave information in standard for cyclone-exposed sites

Duration: 36 months | **Launched:** 2022

Objective:
› To better characterise extreme wind and waves during tropical cyclones to optimise the design of offshore wind turbines exposed to such risks.

Scientific and technical content:
› Creation of a database of existing information on winds and waves associated with tropical cyclones.
› Validation and improvement of parametric surface wind models, then extrapolation to hub height.
› Validation, improvement and extension towards coastal waters of the parametric wave model from Kudryavtsev *et al.*.
› Development of a method for estimating wind and wave joint extremes.
› Application of the new method to two sites of interest and comparison to standard practices.

2023 achievements:
› Compilation of a set of data, measurements and models relating to tropical cyclones.
› Data analysis to characterise the effect of the earth on wind fields and on vertical wind speed profiles.
› Refinement of parametric models of wind and wave fields in cyclones and initiation of more advances wave simulations.
› Development of a complete extreme analysis chain for cyclonic conditions in order to define the characteristics of cyclones according to the desired return periods.

Partners:
This project is led by France Energies Marines.

Total project budget: €1,266K
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 France 2030 investment plan.
It also receives funding from the maritime cluster Pôle Mer Bretagne Atlantique.

POWSEIDOM

Deployment of wind and turbulence observations in the Mediterranean

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

Objectives:
› 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, i.e. with an acquisition frequency four times higher than a commercial lidar of the same type.
› Preliminary study of the lidar's capacity to measure turbulence by comparison with a met 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.

2023 achievements:
› Analysis of data from the measurement campaign carried out with a lidar mounted on a hexapod reproducing the movement of a buoy and a stationary lidar as a reference in order to develop a movement correction algorithm.
› Collection of one year of uninterrupted wind measurements, in particular turbulence, using a profiling lidar installed on Planier Island to generate conditions representative of an offshore site.

2023 dissemination:
› Presentations:
  • Delafosse C. (2023) Caractérisation de sites - Quels sont les enjeux pour la conception, le suivi et la maintenance des parcs éoliens flottants ? Tribune scientifique et technologique de France Energies Marines, Montpellier, France, 14/12/2023
  • Guinot F. (2023) Building a bridge between oceanographic and wind developments: Application on turbulence intensity characterization and noise removal from profiling pulsed lidar measurements. Wind Energy Science Conference, Glasgow, Royaume-Uni, 23/05/2023 - 26/05/2023
  • Thiébaut M. (2023) Quantification of the error induced by floating lidar motions in wind vector and turbulence intensity estimation. Wind Energy Science Conference, Glasgow, Royaume-Uni, 23/05/2023 - 26/05/2023
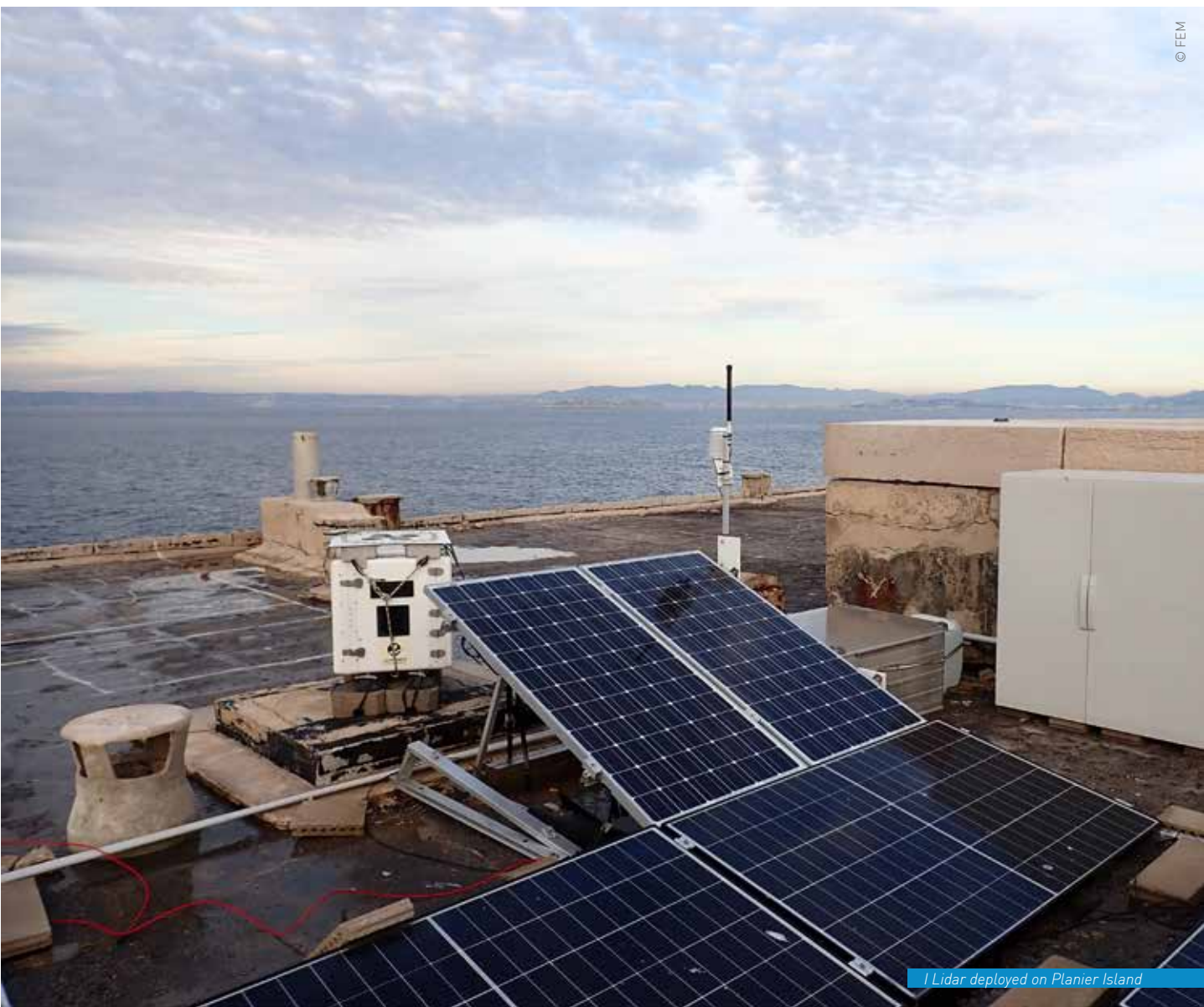
Partners:
This project is led by France Energies Marines.

Site characterisation

© FEM

I Lidar deployed on Planier Island

BAMOS

Behaviour and ageing of mooring using synthetic rope

Duration: 42 months | **Launched:** 2023

Objective:
› To improve the modelling of short- and long-term behaviour of nylon ropes and expand knowledge of fatigue and degradation mechanisms.

Scientific and technical content:
In-depth modelling of polyamide ropes
› Development of a meso-scale model.
› Enhancement of 1D behaviour law for rope.
› Experimental campaigns.

Investigations into fatigue mechanisms
› Extension of the fatigue curve at low tension range.
› Fatigue prediction method using self-heating approach.
› Investigation into the parameters influencing the fatigue curve.
› Definition of a new criterion for fatigue prediction.

Validation of polyamide rope behaviour law and degradation processes
› Laboratory validation of behaviour law on a full-scale rope.
› Impact of selected rope model on mooring design.
› Extended sea trials, review of degradation rope mechanisms, ropes inspection and tests after dismantling.

2023 achievements:
› Project launch in November and initiation of various scheduled activities.

Partners:
This project is led by ENSTA Bretagne and France Energies Marines.

Total project budget: €2,255K
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 France 2030 investment plan.
It also receives funding from the Brittany, Pays de la Loire and SUD Provence-Alpes-Côte d'Azur regions.
This project is approved by the maritime cluster Pôle Mer Bretagne-Atlantique.

BIODHYL

Biofouling integrative characterization and description of hydrodynamic loadings

Duration: 40 months | **Launched:** 2022

Objectives:
› To gain a better understanding of the characteristics of biofouling organisms and the environmental parameters that influence biofouling.
› To predict the environmental and hydrodynamic effects of biofouling.

Scientific and technical content:
› *In situ* characterisation of biofouling and study of the influence of parameters such as immersion time, depth, physico-chemical conditions, and site hydrodynamics.
› Development of methodologies to combine a morphological approach and metabarcoding to better characterise biofouling.
› Definition and characterisation of hydromechanical biofouling groups based on the different fluid-structure behaviours presented in the scientific literature and refined by mechanical tests.
› Building of a generic full-scale numerical model of a floating wind system including moorings and dynamic cable.
› State-of-the-art review of technologies to automate the recognition and metrology of biofouling, then benchmark qualification.

2023 achievements:
› Development of a sampling protocol for all observation sites.
› Design and manufacture of innovative devices on which to mount samples of moorings and power cables.
› Development of a methodology to characterise the oscillating fluid dynamics associated with waves, including the identification of an appropriate sensor technology and the definition of a specific sampling procedure.
› Beginning of deployment and monitoring operations at sea in November, following the immersion of the sample-carrying devices on the APPEAL buoy in southern Brittany.

2023 dissemination:
› Publications:
  • Portas A. (2023) Biofouling dans le contexte des énergies marines renouvelables : étude des communautés procaryotes et eucaryotes et des paramètres physiques structurants (Thèse de doctorat) Ecole doctorale Mer et Sciences, Toulon
  • Portas A., *et al.* (2023) Impact of hydrodynamics on community structure and metabolic production of marine biofouling formed in a highly energetic estuary. *Marine Environmental Research*, Vol. 192, 106241
  • Signor J., *et al.* (2023) Automatic classification of biofouling images from offshore renewable energy structures using deep learning. *Ocean Engineering*, Vol. 288, 115928
› Presentation:
  • Maison A., *et al.* (2023) Numerical analysis on the thermal insulation role of biofouling on dynamic subsea power cables, International Conference on Insulated Power Cables, Lyon, France, 18/06/2023 - 22/06/2023

Partners:

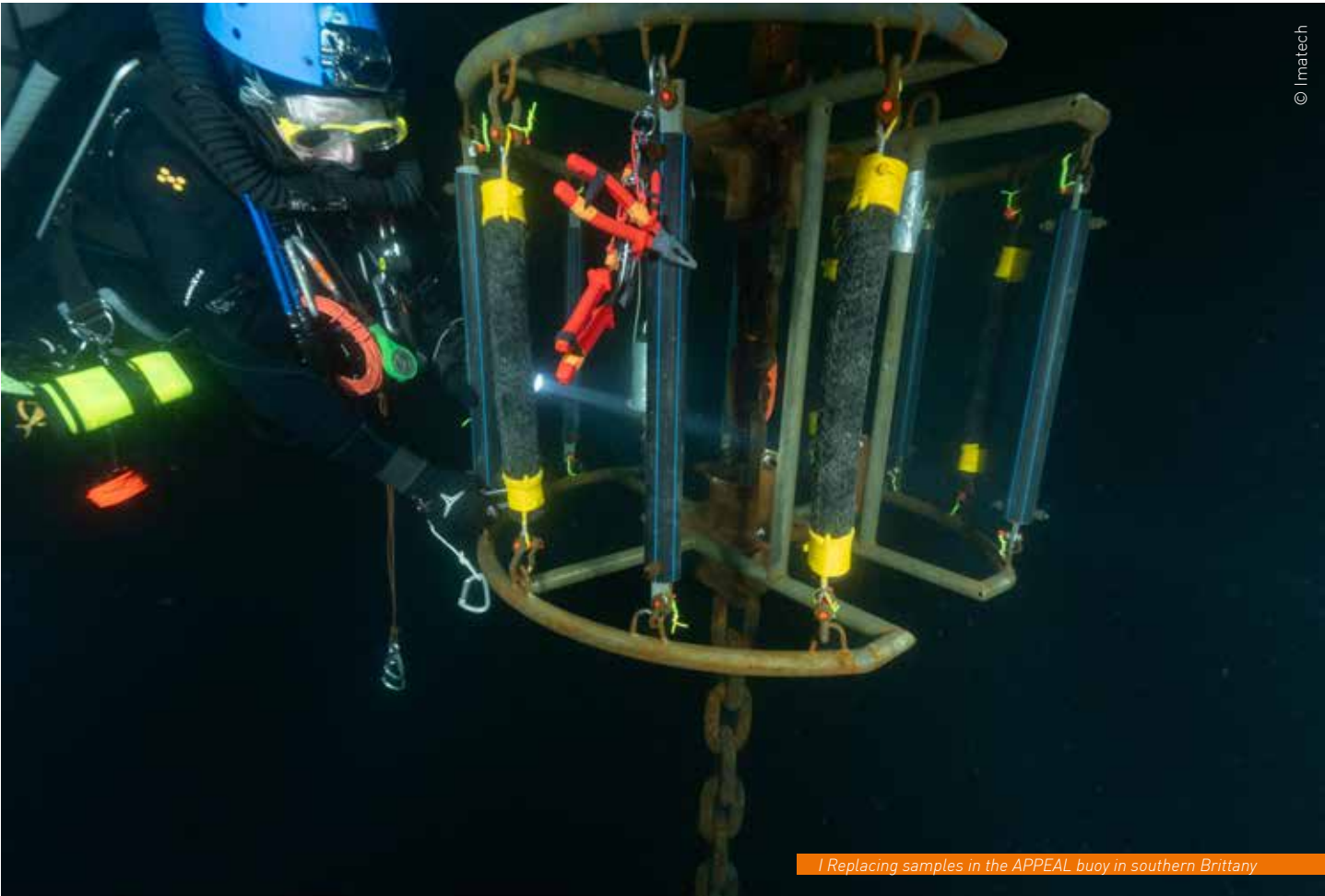This project is led by France Energies Marines.

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| Replacing samples in the APPEAL buoy in southern Brittany

DIONYSOS

Digital intelligent operational network using hybrid sensors/simulations approach

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

Objective:
› 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 the *Unitech Zefyros* offshore wind turbine located off the coast of Norway.
› 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.

2023 achievements:
› Finalisation and training of the *Unitech Zefyros* floating wind turbine numerical model.
› Deployment of the first sensors (Neuron® and an inertial measurement unit) on the offshore wind turbine and finalisation of the data repatriation process.
› Analysis of the initial data received, revealing a good correlation at low frequencies between the global model and the measurements.
› Study of second-order hydrodynamic forces and contribution of the use of the quadratic transfer function (QTF) to the accuracy of the behaviour model developed.
› Signing of a collaboration agreement with an industrial company operating a demonstrator at the Spanish BiMEP test site in order to apply learning-based methods for predicting the behaviour of floating wind turbines to its system.

2023 dissemination:
› Publication:
  • Dridi N., *et al.* (2023) Estimation de l'incertitude pour les réseaux de neurones : application pour la prédiction de mouvement d'éolienne en mer. Actes du colloque GRETSI 2023, ID1278, 4 p.
› Presentations:
  • Hirvoas A. (2023) Digital twin of floating offshore wind turbine for fatigue estimation of key structural elements, FOWT, Nantes, France, 10/05/2023 - 12/05/2023
  • Hirvoas A. (2023) Harnessing the Machine Learning Advancements in Marine Renewable Energies Development. Colloque Data sciences pour les risques côtiers, Roscoff, France, 13/11/2023 – 15/11/2023
  • Romain R. (2023) Development of a digital intelligent operational network using hybrid sensors/ simulations approach, 50th FPSO/FER JIP, Paris, France, 26/06/2023 - 30/06/2023

› Posters:
- Dridi N., *et al*. (2023) Estimation de l'incertitude pour les réseaux de neurones : application pour la prédiction de mouvement d'éolienne en mer, GRETSI'23, Grenoble, France, 28/08/2023 - 01/09/2023
- Mezon C., *et al*. (2023) Détection d'anomalies et de comportements pathologiques d'une éolienne offshore flottante basée sur des capteurs inertiels et des réseaux de neurones pré-entrainés sur des données synthétiques, Colloque Jumeaux Numériques, Paris, France, 09/02/2023
- Ribault R., *et al*. (2023) Anomaly and pathological behavior detection of floating offshore wind turbine based on neuron sensors and simulation models, WindEurope Annual Event, Copenhague, Danemark, 25/04/2023 - 27/04/2023

Partners:
This project is led by France Energies Marines.

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I Floating wind turbine demonstrator to which learning-based behaviour prediction methods will be applied

DYNAMO

In-service monitoring of dynamic cables

Duration: 26 months | **Launched:** 2020 | **Completed:** 2023

Objectives:
› To prepare guidelines for the farm-scale deployment of in-service monitoring solutions for subsea cables.
› To propose a roadmap for the development of in-service monitoring technologies.

Achievements throughout the project:
› Determination of the parameters reflecting the emergence of failure modes, state-of-the-art review of sensors capable of detecting a change in these parameters and promising technologies.
› Acquisition of experimental data on local failure modes during electrical and mechanical test campaigns (bending, compression and tension tests).
› Application of the methodology developed for risk analysis to cases including different farm architectures and failure modes.

2023 dissemination:
› Publication:
  • Recommendations for health monitoring of dynamic cables for floating offshore wind farms (May 2023) Maison A. & Roulet M., 24 p.
› Presentations:
  • Maison A., *et al.* (2023) Testing monitoring technologies on dynamic subsea power cables to detect mechanical failures, Maison A., *et al.* (2023) Numerical analysis on the thermal insulation role of biofouling on dynamic subsea power cables, International Conference on Insulated Power Cables, Lyon, France, 18/06/2023 - 22/06/2023
  • Al Ibrahim A., *et al.* (2023) Electrical diagnosis of dynamic subsea power cables for floating offshore wind farms using a model-based approach, Maison A., et al. (2023) Numerical analysis on the thermal insulation role of biofouling on dynamic subsea power cables, International Conference on Insulated Power Cables, Lyon, France, 18/06/2023 - 22/06/2023

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 France 2030 investment plan.
It also receives funding from EDF Renouvelables and from the Brittany and Pays de la Loire regions.

Design and monitoring

Effective lifetime extension in the marine environment for tidal energy

Duration: 48 months | **Launched:** 2019 | **Completed:** 2023

Objective:
› To use artificial intelligence to develop a control system to optimise the performance of a tidal turbine in turbulent flow, maximise energy yield, increase reliability and extend the lifetime of the turbine.

Scientific and technical content:
› Environmental characterisation of deployment sites, and assessment and modelling of the potential environmental impacts of tidal turbines.
› Design of a control system based on artificial intelligence.
› Onshore testing in a controlled environment, followed by tests in an estuary and at sea.
› Production of the control system and design of a tidal turbine based on the results of these tests.
› Socio-economic assessment of tidal turbine energy at regional, national and European levels.

Achievements throughout the project:
› Testing of the tidal turbine in estuarine (Ria d'Etel) and offshore (Shetland) environments combined with a socio-economic assessment.

2023 dissemination:
› Publication:
  • Portas A., *et al.* (2023) Impact of hydrodynamics on community structure and metabolic production of marine biofouling formed in a highly energetic estuary. *Marine Environmental Research*, Vol. 192, 106241
› Event:
  • Organisation of a public presentation of the experimental tidal turbine on 9 February prior to its immersion in the Ria d'Etel.

Partners:
This project is coordinated by Nova Innovation.

Total project budget: €4,895K
This project receives funding from the Horizon 2020 European research and innovation programme (grant agreement no. 815180).

I Members of the project team in front of the tidal turbine prior to its immersion in the Ria d'Etel

Design and monitoring

Electrical connection hub and application for a 20 MW wind turbine

Duration: 36 months | **Launched:** 2023

Objective:
› To design, test and certify a high-voltage rotating mechanical and electrical connection that is watertight and maintenance-free for 10 years.

Scientific and technical content:
› Parameterisation and coding of the behaviour of polyamide mooring lines in commercial software.
› Identification of failure modes for mooring lines and dynamic cables.
› Local and global numerical modelling of the dynamic cable, performance of sea trials for in-service monitoring.
› Fatigue testing of dynamic cables and mechanical testing of mooring lines.
› Analysis of standards and certifications for mooring lines and electrical connections.
› Design and full-loading analysis of a 20 MW wind turbine.
› Design, manufacture and assembly of the mechanical and electrical parts of the rotating connection.
› Tank tests on a reduced-scale model of the 20 MW wind turbine.

2023 achievements:
› Beginning of work on the state-of-the-art review of failure modes.
› Launch of a call for expressions of interest, in collaboration with the maritime cluster Pôle Mer Bretagne Atlantique, to test sensor technologies capable of recording dynamic cable deformation in time and space.

Partners:
This project is led by Eolink.

Total project budget: €6,194K
This project receives funding from the French Agency for Ecological Transition (ADEME), Corimer, BPI France and the France 2030 investment plan.

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

I Electrical connection hub and application for a 20 MW wind turbine

MONAMOOR

Modelling and monitoring of polyamide mooring lines

Duration: 42 months | **Launched:** 2020 | **Completed:** 2023

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 degradation mechanisms.

Achievements throughout the project:
› Improvement and validation of a nylon behaviour law established during a previous project (POLYAMOOR from 2017 to 2020).
› Long-term laboratory creep tests.
› Fatigue tests, X-ray tomography analysis of ropes, use of the self-heating method.
› Development of a 3D mesoscale finite element model of a subrope.
› Increase in the technological readiness level of various innovative sensors: elongation (wire, ultrasound, fibre optics), pressure, acoustic emission.
› Design, assembly and deployment at sea of a demonstrator capable, on a reduced scale, of representing the forces generated by a floating wind turbine.
› Sea trials to validate the behaviour law and some of the sensors developed.

2023 dissemination:
› Publication:
  • Civier L. (2023) Suivi des lignes d'ancrage en polyamide pour les éoliennes offshore (Thèse de doctorat), Ecole doctorale des sciences pour l'ingénieur et le numérique
› Event:
  • Organisation of a webinar, held on 30 November and attended by 95 participants, to present the project results.

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 France 2030 investment plan.

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

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

Farm optimisation

Architecture and design of a floating offshore substation for direct current applications

Duration: 36 months | **Launched:** 2022

Objective:
› To study the high-voltage direct current floating offshore substation as an integrated system through analyses of functional requirements, integration constraints, risk and reliability.

Scientific and technical content:
› **Design basis:** global market analysis, definition of geographic sites and collection of metocean data, definition of farm and grid connection scenarios.
› **Electrical systems and topside:** functional analysis, electrical components list, electrical architecture definition, topside arrangement, calculation of the movements of the assembly.
› **Semi-submersible platform:** design, motion and vibration analysis.
› **Tension-leg platform (TLP):** advanced and comparative design, motion and vibration analysis, basin testing.
› **Dynamic cables:** design of a cross-section, definition of their arrangement and connection.
› **Cybersecurity:** architecture and mapping, risk analysis, mitigation measures.
› **System integration:** risk and reliability analysis, maintenance optimisation, OPEX calculation.
› **Qualification:** validation and qualification strategy, rules and regulation gap analysis, recommendations.

2023 achievements:
› Selection of study sites and analysis of site conditions.
› Finalisation of the design basis for the future direct current floating substation, as well as the definition of the electrical systems and the general topside arrangement.
› Launch of the study on the float with taut mooring lines with a literature review and a review of projects carried out in the oil & gas industry.

Partners:
This project is led by France Energies Marines.

Total project budget: €1,491K

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 France 2030 investment plan.
It also receives funding from the Occitanie, Pays de la Loire and SUD Provence-Alpes-Côte d'Azur regions.

Farm optimisation

Floating offshore wind turbines
operation and maintenance

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

Objectives:
› 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.

2023 achievements:
› Finalisation of the benchmarking of heavy maintenance solutions at sea and selection of the technology to be studied in detail for the project.
› Development of hydrodynamic models based on two float technologies (semi-submersible and taut mooring) to carry out heavy lift testing using numerical simulations.
› Case study simulations of heavy maintenance operations.
› Finalisation of the specifications for future tank tests and the production of models.
› Production of a first version of the user specifications for the short-term metocean forecasting tool.

2023 dissemination:
› Publication:
  • Marcille R., *et al.* (2023) Gaussian mixture models for the optimal sparse sampling of offshore wind resource. *Wind Energy Science*, Vol. 8, pp.771-786
› Presentations:
  • Marcille R. (2023) Deep-Learning based ultra-short-term forecasting of met-ocean variables for the planification and execution of floating wind O&M, FOWT, Nantes, France, 10/05/2023 - 12/05/2023
  • Marcille R. (2023) Prévisions météo-océaniques et enjeux de dérisquage pour les projets éoliens en mer. Colloque Data sciences pour les risques côtiers, Roscoff, France, 13/11/2023 – 15/11/2023
  • Marcille R. (2023) Caractérisation de sites - Quels sont les enjeux pour la conception, le suivi et la maintenance des parcs éoliens flottants ? Tribune scientifique et technologique de France Energies Marines, Montpellier, France, 14/12/2023
› Poster:
  • Marcille R., *et al.* (2023) Deep learning for the multivariate probabilistic forecasting of wind speed: application to floating offshore wind operations and maintenance. WindEurope Annual Event, Copenhagen, Denmark, 25/04/2023 - 27/04/2023

Partners:

This project is led by France Energies Marines.

| Floating wind farm and metocean forecasts

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Boosting the hydrogen transition in the Atlantic Area ports

Farm optimisation

Duration: 36 months | **Launched:** 2023

Objectives:
› To assess, develop and promote the use of technologies based on green hydrogen from renewable energies in Atlantic Area ports.

Scientific and technical content:
› **Analysis of the current situation and opportunities in Atlantic Area:**
  • Mapping of hydrogen initiatives in place and planned.
  • Identification of the most promising hydrogen applications and the associated benefits, bottlenecks, and solutions.
  • Identification of opportunities in HYDEA ports.
› **Case studies, business models and decision support system:**
  • Definition of case studies for each HYDEA port, then technical, economical, environmental, and social assessment.
  • Development of new hydrogen services and port business models.
  • Development of a decision support system to facilitate the selection of hydrogen technologies.
  • Reconstruction of offshore wind metrics using data-driven methods.
› **Solutions and pilot projects using hydrogen-based technologies:**
  • Setting up of different demonstration activities in Spain, Portugal, France, and Ireland.
  • Support for other agents to test and/or develop their technologies and hydrogen business models.
› **Capitalisation:**
  • Development of a community comprising the entire hydrogen value chain.
  • Transfer of knowledge, best practices, and innovations.
  • Preparation of action plans for HYDEA ports.
  • Preparation of a roadmap for the implementation of hydrogen in the Atlantic area ports.

2023 achievements:
› Project launch in November and initiation of various scheduled activities.

Partners:
This project is led by EnergyLab.
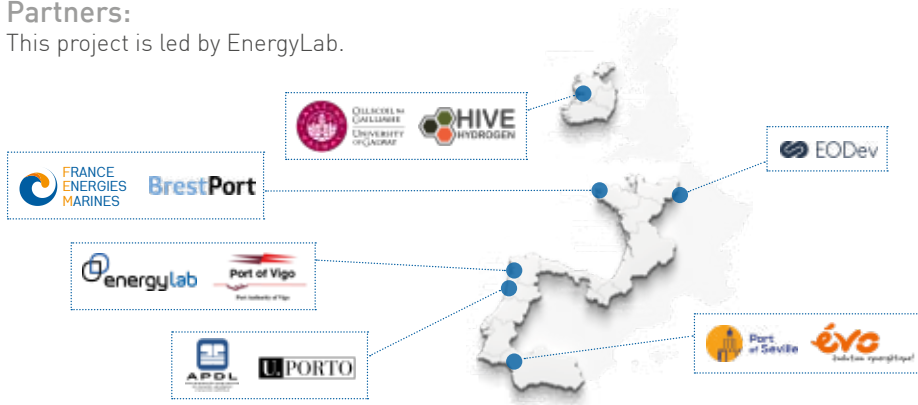
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I Container terminal at the port of Leixões in Portugal

MOSISS

Monitoring strategies for innovative substations

Duration: 29 months | **Launched:** 2020 | **Completed:** 2023

Objective:
› To develop and demonstrate a comprehensive methodology for in-service electrical and mechanical monitoring of floating offshore electrical substations.

Achievements throughout the project:
› Gathering of feedback on the operation and maintenance of electrical substations with and without in-service monitoring, definition of specific requirements for optimising OPEX.
› Identification of offshore substation failure risks and the degradation processes of certain components, then development of a global methodology for optimised electrical and mechanical maintenance.
› Demonstration of this methodology at system level based on five case studies (inspection and/or in-service monitoring at various frequencies and to varying extents) including different scenarios, at three different sites (North Pacific, North Atlantic and Mediterranean).

2023 dissemination:
› Publication:
  • Schoefs F., *et al*. (2023) Unified System Analysis for Time-Variant Reliability of a Floating Offshore Substation. *Marine Science and Engineering*, Vol. 11, 1924

Partners:
This project is led by Nantes University 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 France 2030 investment plan.
It also receives funding from EDF Renouvelables and the Pays de la Loire region.

l Floating offshore substation
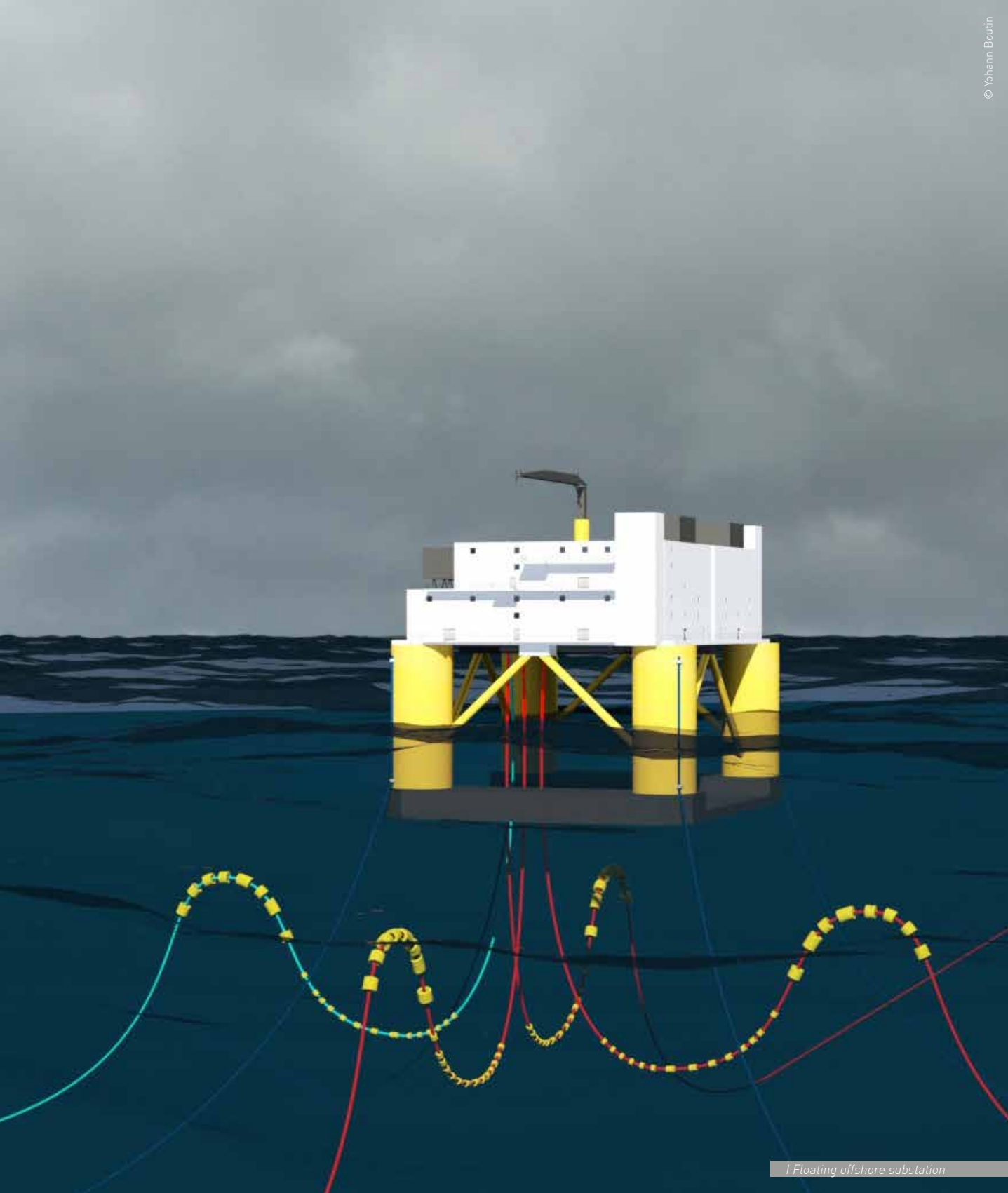
MUTANC

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.

2023 achievements:
› Finalisation of coupled numerical studies of the NREL 15 MW floating wind turbine on a semi-submersible float, as well as mooring system design and analysis at several water depths and with shared mooring systems.
› Beginning of geotechnical numerical modelling work and experimental centrifuge work.

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 France 2030 investment plan.
It also receives funding from the Pays de la Loire region and from the maritime cluster Pôle Mer Bretagne Atlantique.

I Shared anchors for floating offshore wind turbines

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Farm optimisation

Offshore production of hydrogen analysis and roadmap

Duration: 24 months | **Launched:** 2021 | **Completed:** 2023

Objective:
› To produce decision-support tools for hydrogen production coupled with offshore wind energy.

Achievements throughout the project:
› State-of-the-art of existing hydrogen production, storage and transport technologies.
› European mapping of hydrogen projects, infrastructures and users coupled with wind resources.
› Analysis of market potential in Europe.
› Organisation of a series of eight regional technical workshops to build realistic scenarios.
› Development of a tool for the assessment of hydrogen production configurations coupled with offshore wind, and preparation of associated documentation.
› Use of the tool for four regional case studies.
› Review of safety and environmental risks, including associated standards and regulations.
› Roadmap for the offshore wind energy sector relating to R&D actions to be carried out in mainland France.

Partners:
This project is led by France Energies Marines.

Total project budget: €544K
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 France 2030 investment plan.
It also receives funding from the Normandy, Pays de la Loire and SUD Provence-Alpes-Côte d'Azur regions.
This project is approved by the maritime cluster Pôle Mer Méditerranée.

I Decision-support tools for hydrogen production coupled with offshore wind energy

Farm optimisation

Advanced analysis for offshore production of hydrogen from offshore wind

Duration: 36 months | **Launched:** 2023

Objective:
› To address a series of complementary aspects of renewable hydrogen production from offshore wind farms to support its progress towards operational deployment, including the integration in energy networks, technological aspects and environmental impacts.

Scientific and technical content:
› **Network integration**
  • Coastline scale study: Channel, Atlantic and Mediterranean coasts.
  • Local scale study: Marseille-Fos harbour and industrial site.
› **Technology specifications and design**
  • Panorama of involved technologies.
  • Specifications and design of a wind turbine + electrolysis system, and substation + electrolysis system.
› **Impact of movement on the performance of a proton exchange membrane electrolyser**
  • Definition of case studies for testing.
  • Simulation of the movements of a wind turbine and a substation.
  • Testing of the performance of an electrolyser with simulated movement.
› **Environmental integration**
  • Identification of the different pressure-receptor pairs: chronic risk, accidental risk, impacts on marine compartments.
  • Risk characterisation related to brine discharges in offshore wind farms.
  • Characterisation of physicochemical and biological impacts of brine.

2023 achievements:
› Project launch in October and initiation of various scheduled activities.

Partners:
This project is led by France Energies Marines.

Total project budget: €544K
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 France 2030 investment plan.
It also receives funding from the Brittany, Pays de la Loire, Occitanie and SUD Provence-Alpes-Côte d'Azur regions.
This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.

Hydrogen production by offshore wind turbines

Farm optimisation

Multi-criteria optimisation for offgrid marine renewable electrical production

Duration: 36 months | **Launched:** 2022

Objective:
› To propose economic and environmental solutions for the supply of isolated electrical grids.

Scientific and technical content:
› Bibliography on offshore renewable energy sources and storage: price, maintenance, reliability, lifetime, system life cycle, CO_2 impact, implantation.
› Calculation of key performance indicators for a multi-criteria approach: failure, machine position, cost, optimised electricity price.
› Development and implementation of a multifactor joint optimisation method.
› Real-time simulation of an electrical network taking into account cybersecurity aspects.
› Application cases: island, aquaculture and oil & gas infrastructures.

2023 achievements:
› Definition of the methodology and reliability of the multi-criteria approach.
› Continuation of design work on the power supply to an isolated microgrid generated by offshore renewable energy sources.

2023 dissemination:
› Presentations:
  • Dupriez-Robin F & Roux F. (2023) Isolated microgrid supply by offshore renewable energy - Improve reliability with inspection and monitoring. 7th Offshore Energy & Storage Symposium, Saint-Julian, Malta, 12/07/2023 - 14/07/2023
  • Dupriez-Robin F & Roux F. (2023) OPTILE: A Collaborative Project for the Optimisation and Simulation of Isolated Electrical. 15th International Conference on Real-Time Simulation, Lisbon, Portugal, 13/11/2023 – 16/11/2023

Partners:
This project is led by France Energies Marines.

I Supplying an island grid with offshore renewable energy

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ECOCAP

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 corrosion protection systems commonly used in the offshore renewable energy industry.

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 report comprising recommendations for offshore wind stakeholders.

2023 achievements:
› Organisation of two new measurement campaigns for metals and chlorinated and brominated components in the Atlantic Ocean and Mediterranean Sea
› Finalisation of laboratory-based toxicity tests on elements released by galvanic anodes and impressed current protection systems on several species at different trophic levels: microalgae, oysters, sea urchins, shrimps, cuttlefish and fish.
› Continuation of chemical risk assessments on cathodic protection systems.

2023 dissemination:
› Presentations:
  • Dussauze M. (2023) Chemical risk assessment in the context of ORE: the case of cathodic protections. Feedback from methodologies initiated by France-Energies-Marines and its partners. Anemoi Stakeholder Event, Hamburg, Germany, 30/05/2023 - 31/05/2023
  • Dussauze M. (2023) Projet ECOCAP - Evaluation de la toxicité des dispositifs anti-corrosion. Rencontres Recherche & Industrie pour innover - Focus éolien flottant en mer, Sète, France, 23/11/2023
  • Michelet M. (2023) Caractérisation de sites - Quels sont les enjeux pour la conception, le suivi et la maintenance des parcs éoliens flottants ? Tribune scientifique et technologique de France Energies Marines, Montpellier, France, 14/12/2023
› Poster:
  • Blanc M. (2023) Offshore renewable energy: toxicity of metallic elements released in the marine environment by anticorrosive protections. SETAC Europe 33rd Annual Meeting, Dublin, Ireland, 30/04/2023 – 04/05/2023

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

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I Northern shrimp viewed with a stereo microscope

EOLENMER

Monitoring the socio-economic impacts of offshore wind farms

Duration: 48 months | **Launched:** 2023

Objectives:
› To develop a system of monitoring indicators and methodologies to characterise the impact of offshore wind farms on human activities, stakeholders and local areas.
› To obtain concrete information and initial feedback on the impact of offshore wind farms on French coastal areas.

Scientific and technical content:
› Definition of a territorial analysis to inventory the local challenges and stakeholders at six study sites across three coastlines.
› Thematic monitoring of the impacts of offshore wind farms on the environment (marine and terrestrial), uses, industries and territories, along the land-sea continuum, preferably on an annual basis and in line with current scientific approaches in the various fields.
› Open, interdisciplinary and participatory monitoring, covering emerging issues relating the changes underway in the local areas, to open them up to public debate.

2023 achievements:
› Contribution to the state-of-the-art review on local areas, in particular by carrying out territorial analyses on several coastlines, and conducting targeted interviews with stakeholders in the tourist industry.
› Monitoring of the French public debate on maritime planning entitled *La mer en débat* launched in late 2023.

Partners:
This project is led by the Pacte laboratory and the CIRED (Centre international de recherche sur l'environnement et le développement).

Total project budget: €4,521K
This project receives funding from the French Agency for Ecological Transition (ADEME).

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I Monitoring the socio-economic impacts of offshore wind farms

FISH INTEL

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

Duration: 24 months | **Launched:** 2021 | **Completed:** 2023

Objectives:
› 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 offshore renewable energy 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.

Achievements throughout the project:
› Deployment of acoustic telemetry receivers at seven pilot sites in France, England and Belgium. In France, deployment of more than 60 receivers in the Iroise Sea, off Côtes d'Armor and in the Bay of Seine.
› Acoustic tagging of almost 900 individuals, including various species of fish and spiny lobsters, with more than 300 individuals in France.
› Receiver reading campaigns and downloading of monitoring data.
› Conducting of a survey among recreational fishermen in the Channel, focusing mainly on their well-being, their fishing activity and their opinion of current management measures.
› Awareness-raising among local stakeholders.
› Development of software via which stakeholders can access and use the monitoring data.

2023 dissemination:
› Events:
  • Organisation of a workshop on 24 January in Brest and on 8 February in Port-en-Bessin to present the results of the acoustic telemetry monitoring of sea bass, pollock and bluefin tuna to local stakeholders.
  • Organisation on 2nd March of a public meeting in Plymouth, UK, to present the project results

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.

I Acoustic telemetry system before being deployed

Environmental integration

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

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.

2023 achievements:
› Integration of a seventh study site: 12 receivers deployed at the Île d'Yeu and Île de Noirmoutier wind farm site and 20 lobsters fitted with acoustic tags.
› Acoustic tagging of a total of 301 individuals of 9 different species since the start of the project, in the Channel, Atlantic and Mediterranean.
› Receiver reading campaign and collection of monitoring data.
› Uploading of data to the European Tracking Network (ETN) platform.
› First large-scale movement analyses to study regional movements and habitat connectivity.

2023 dissemination:
› Presentations:
  • Couturier L., *et al*. (2023) Monitoring the habitat use and movements of mobile species in a context of offshore wind energy development. Conférence Internationale d'Océanographie, Caen, France, 24/10/2023 – 27/10/2023
  • Couturier L., *et al*. (2023) Monitoring occupancy patterns of fish with offshore wind farms – in a nutshell. International Conference on Fish Telemetry, Sète, France, 11/06/2023 - 16/06/2023
  • Labourgade P., *et al*. (2023) Multi spatial-scales approach in acoustic telemetry reveals intraspecific variability in habitat use and behaviour of the undulate ray (Raja undulata) within an estuary. International Conference on Fish Telemetry, Sète, France, 11/06/2023 - 16/06/2023
› Poster:
  • Couturier L. (2023) Effective monitoring strategies to identify and evaluate effects of offshore wind farms and their export cable on fish and large crustaceans. 7th Conference on Wind Energy and Wildlife Impacts, Šibenik, Croatia, 18/09/2023 - 22/09/2023
› Events:
  • Awareness-raising about the project and its preliminary results among local stakeholders, including fishermen, at various meetings organised in Brest, Saint-Brieuc, Port-en-Bessin and Le Croisic.
  • Organisation of a public information webinar on 10 November, attended by 124 people.
  • Organisation on 6 December in Nantes of a workshop for stakeholders involved in acoustic telemetry, to jointly define the next areas of focus for R&D projects.

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 France 2030 investment plan.

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

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

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| End of a tagging campaign in the Saint-Nazaire wind farm area

LIF-OWI

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

Duration: 36 months | **Launched:** 2020 | **Completed:** 2023

Objectives:
› To develop a comprehensive methodological framework for environmental and social life cycle assessment (LCA), 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 LCA.

Achievements throughout the project:
› Building of a parameterised LCA model to assess the environmental performance of offshore wind farms and their connections.
› Development of a new biodiversity indicator (bird collision indicator) to be included in the environmental LCA.
› Development of a social LCA methodological framework applicable to offshore wind farms.
› Development of an employment assessment model.
› Building of an online platform to conduct prospective LCAs on the environmental and socio-economic impacts of wind farms.

2023 dissemination:
› Publications:
  • Lehmann J. (2023) Intégration de l'analyse du cycle de Vie Sociale comme outil d'évaluation et d'aide à la prise de décision dans la phase de conception des projets de parcs éoliens en mer en France (Thèse de Doctorat). Ecole doctorale Ingénierie des systèmes, matériaux, mécanique, énergétique, Sophia Antipolis
  • Lehmann J., *et al.* (2024) Hierarchization of social impact subcategories: towards a systematic approach for enhanced stakeholders' representativeness. *The International Journal of Life Cycle Assessment*
  • Baulaz Y., *et al.* (2024) Development of a collision impact indicator to integrate in the life cycle assessment of offshore wind farms. *The International Journal of Life Cycle Assessment*

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

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 France 2030 investment plan.
It also receives funding from the Normandy region.

I Life cycle assessment of offshore wind farms

NESTORE

Nested modelling approach for offshore wind farms development and cumulative impact assessment considering local to regional environmental and socio-economic stakes

Duration: 36 months | **Launched:** 2022

Objective:
› To develop appropriate tools to study the cumulative impacts of offshore wind farms and other human activities on marine ecosystems

Scientific and technical content:
› A comprehensive analysis of the French strategic coastal planning documents for marine ecosystem management and nested mapping of the associated local and regional challenges.
› Development of a set of nested trophic modelling tools at different spatial scales to assess the cumulative impact of offshore wind farms and other human activities.
› Improvement of the consideration of uncertainty in models' predictions by coupling different model approaches and data availability.
› Production of different management scenarios comprising local and regional challenges, including mapping showing the evolution of ecosystem services related to offshore wind farms development.

2023 achievements:
› Definition of a roadmap framework for the study of the cumulative impacts resulting from the development of offshore wind farms, based on an analysis of French strategic coastal planning documents, European directives and the French sea and coastline strategy.
› Parameterisation and calibration work on two ecosystem models, for Eastern Channel-Southern North Sea and Southern Brittany coastlines, to integrate cumulative impact simulations.

2023 dissemination:
› Presentations:
  • Baulaz Y. & Mouchet M. (2023) Ecosystem services spatially linked to environmental and socio-economic stakes in the context of offshore wind farm development. Conférence Internationale d'Océanographie, Caen, France, 24/10/2023 – 27/10/2023
  • Esnard P., *et al*. (2023) Regulatory and planning aspects of wind energy projects. Conférence Internationale d'Océanographie, Caen, France, 24/10/2023 – 27/10/2023
  • Le Marchand M., *et al*. (2023) Combined impacts of climate change and non-indigenous species arrivals on Bay of Biscay trophic network structure and functioning. International Society for Ecological Modelling Global Conference, Toronto, Canada, 02/05/20233 - 06/05/2023
› Posters:
  • Baulaz Y., *et al*. (2023) A general methodological framework to quantify the supply of marine ecosystem services in the context of offshore renewable energy development. WindEurope Annual Event, Copenhagen, Denmark, 25/04/2023 - 27/04/2023
  • Esnard P., *et al*. (2023) Offshore wind planning and cumulative impacts assessment: an analysis of regulatory and operational issues in France. 7th Conference on Wind Energy and Wildlife Impacts, Šibenik, Croatia, 18/09/2023 - 22/09/2023

Partners:

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

Total project budget: €3,344K

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 France 2030 investment plan.
It also receives funding from the SUD Provence-Alpes-Côte d'Azur, Brittany and Normandy regions.

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I Fécamp offshore wind farm

Environmental integration

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

Duration: 36 months | **Launched:** 2020 | **Completed:** 2023

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

Achievements throughout the project:
› Implementation of 14 marine megafauna aerial monitoring campaigns with visual and digital data acquisition at different altitudes at 5 offshore wind farm sites and during various seasons.
› Definition and distribution of a data format for processing digital images.
› Calculation of inter-calibration indices for marine megafauna monitoring methods and analysis of their variability.
› Development of algorithms for the automated detection of seabirds and marine mammals.
› Provision of an open source R package to simulate datasets for the distribution and abundance of seabirds and marine mammals.
› Methodological and practical recommendations to facilitate and harmonise megafauna monitoring, both via overflights and instruments deployed at sea.
› Preparations to deploy a network of sensors on a met mast off Fécamp to record continuous and synchronous observation data relating to seabirds and marine mammals.

2023 dissemination:
› Presentations:
- Hamard Q., *et al.* (2023) Deep learning for marine mammal monitoring from underwater acoustic data at offshore windfarm scale. Journée des Jeunes Bioaousticien·nes, Unieux, France, 28/06/2023 – 30/06/2023
- Hamard Q., *et al.* (2023) Deep learning for marine mammal monitoring from underwater acoustic data at offshore windfarm scale. 7th Conference on Wind Energy and Wildlife Impacts, Šibenik, Croatia, 18/09/2023 - 22/09/2023
- Heerah K. & Authier M. (2023) Table ronde « Mégafaune marine et parcs éoliens en mer – Quels enjeux et méthodologies de suivi ? ¨, Tribune scientifique et technologique de France Energies Marines, Montpellier, France, 14/12/2023
› Poster:
- Queroué M., *et al.* (2023) Assessing the comparability of different aerial monitoring methods of marine megafauna. 7th Conference on Wind Energy and Wildlife Impacts, Šibenik, Croatia, 18/09/2023 - 22/09/2023

Partners:

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

Total project budget: €1,447K

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SEMAFOR

Observation and prediction of bird migration from weather radars

Duration: 36 months | **Launched:** 2022

Objective:
› To develop a real-time monitoring tool for bird flights and migration via the Météo-France weather radar network.

Scientific and technical content:
› Analysis of the state-of-the-art, feedback and framing of the study.
› Development and validation of an algorithm for the detection of bird echoes on radar echoes.
› Field calibration/validation protocol.
› Construction of a predictive model of bird flows on the maritime facades.

2023 achievements:
› Adaptation of the Vol2Bird detection algorithm to data from the network of weather radars for mainland France.
› Building of a bird migration predictive model to provide a better understanding of the correlations between migratory flows and weather conditions.

2023 dissemination:
› Presentation:
 • Roy A., *et al.* (2023) Predictive modelling of bird migration flows using weather radars. Vertical Space Use of Flying Animals Symposia, 14th European Ornithologists' Union Congress, Lund, Suède, 25/08/2023
› Event:
 • Organisation of an interdisciplinary expert workshop in December at the Swiss Ornithological Insitute in Sempach, to define a roadmap for improving the processing of weather radar data with a view to modelling short-term forecasts.

Partners:
This project is coordinated by France Energies Marines.

Total project budget: €840K
This project receives funding from French Agency for Ecological Transition (ADEME).

I Observing bird migration using weather radars

Environmental integration

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

Duration: 36 months | **Launched:** 2019 | **Completed:** 2023

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

Achievements throughout the project:
› 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 an end-to-end deep neural network and detection of anomalies 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.
› Production and broadcasting of a popularisation video presenting the project and the results obtained.

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.

I Aerial observation of marine mammals

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3 QUESTIONS for...
Maxime Thiébaut

Metocean Data Analysis Researcher
France Energies Marines

What topics do you work on for the Institute?

To begin with, my work was centred on ocean turbulence. With the shift in the offshore renewable energy market towards offshore wind, I now focus on atmospheric turbulence. The theoretical basis remains the same, because water and air are both fluids, but I needed to gain new skills in relation to instrumentation.

Our research aims to provide wind farm developers with reliable, accurate information on turbulence intensity at the sites concerned, in order to optimise turbine design and layout. This information is obtained through reference field measurements taken with an anemometer. However, this instrument, deployed on met masts, is poorly suited to remote offshore sites. The use of remote sensing devices such as lidar is promising, yet still requires further development. This was the reason behind the POWSEIDOM research project, which came to a close last April.

What were the highlights of the POWSEIDOM project?

For this project, we deployed a lidar on Planier Island in the Mediterranean. We were able to challenge the WindCube profiler technology developed by Vaisala, a project partner, to improve the accuracy of turbulence measurements. We also compiled an unprecedented database of measurements recorded over a one-year period, which were then post-processed using specially developed tools. The database contains key information for industry players, including turbulence intensity, average wind speed and direction, and low-level jets. As the ultimate aim was to be able to take measurements at sea with a lidar installed on a buoy, we developed a preliminary motion compensation algorithm based on an innovative spectral approach. This algorithm will be validated during the DRACCAR-NEMO project launched in November 2023, which we are jointly coordinating together with Germany's Fraunhofer Institute for Wind Energy Systems (Fraunhofer IWES) and which follows on from POWSEIDOM.

What are the benefits of working with Fraunhofer IWES?

It is an internationally recognised institute in the field of wind energy. Fraunhofer IWES is to provide us with a dataset acquired in the North Sea that will enable us to validate the above-mentioned algorithm. More broadly, the project aims to jointly develop a new methodology combining lidar measurements and modelling to produce an accurate and reliable spatio-temporal representation of turbulence intensity. This collaboration is beneficial to both our institutes. Another advantage is that Fraunhofer IWES is very involved in certification processes, which will be a great asset for the tools to be developed as part of the project.

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3 QUESTIONS for...
Laure Civier

R&D engineer specialising in innovative moorings for floating wind turbines
France Energies Marines

What is the BAMOS project?

The BAMOS project is a continuation of the POLYAMOOR and MONAMOOR projects. It aims to improve the design of nylon mooring lines and the monitoring of degradation phenomena, in order to guarantee their reliability and durability in long-term offshore applications. In the past, nylon mooring lines have been used for short-term applications, generally for two to three years. The shift to long-term applications, such as moorings for floating wind turbines, requires a rigorous assessment of their durability over a period of at least 20 years. Until now, no study has validated such a lifespan for nylon ropes. The aim of the BAMOS project is to improve existing models, developed through previous projects, to provide a better understanding of the behaviour of new mooring lines. It includes a 1D model for design purposes and a 3D model for in-depth analysis of degradation mechanisms. This work includes carrying out laboratory testing and processing experimental data in order to put forward fatigue criteria suited to the material.

What results are industrial stakeholders hoping to obtain?

Above all, industrial stakeholders are expecting improvements and new identifications for the 1D law, which was developed and initially validated through at-sea trials. This will provide a new, more complete behaviour law for modelling nylon during the design phases. As far as the 3D model is concerned, they are hoping to obtain a model that can faithfully represent an architecture's response. This will enable them to more effectively optimise their constructions and to develop sensors suited to the in-service monitoring of these architectured ropes. Another major expected outcome for industrial stakeholders is the validation of fatigue life. They expect us to put forward a more tailored fatigue criterion, to facilitate structure design. This understanding of fatigue life is crucial in order to come up with an appropriate design criterion, taking into account the complex visco-elasto-plastic properties of the material. Finally, the at-sea trials carried out using the MONABIOP demonstrator are attracting considerable interest. The study of the mechanical properties of mooring lines after use is particularly eagerly awaited, as it will provide valuable information on the durability and performance of materials in real conditions.

What excites you the most about this project?

There are a lot of exciting aspects. First of all, the opportunity to supervise a PhD student is a very motivating experience for me. Having completed my own PhD thesis as part of the MONAMOOR project, it's very interesting to see things from another perspective, while remaining in line with my research. The experimental part of the project is also stimulating. I'm fortunate to be able to carry out tests, analyse the data and put forward concrete solutions for the final application, particularly in relating to design criteria. What's more, I have the chance to carry out an experimental campaign on samples that have been used during sea trials, which is a very rare and valuable opportunity.

06

SECTOR PROGRAMMES

The Institute's sector programmes are long-term initiatives which draw on offshore research infrastructures. They generate data and results in operational conditions that are crucial for all stakeholders in the offshore wind value chain, in particular start-ups, SMEs and intermediate-sized enterprises. These programmes are designed to gather R&D projects under a shared banner, in order to address a given topic via a cross-disciplinary approach.

The DRACCAR programme

Led by France Energies Marines and strongly supported by the Normandy region through funding from the European Regional Development Fund, the DRAC-CAR sector programme aims to enhance our understanding of the interactions between offshore wind energy and the environment. It utilises the instrumentation of a met mast ideally located in the Channel, off Fécamp, in the immediate vicinity of an offshore wind farm. The Channel, which already hosts strongly developed human activities, is a particular focus for offshore wind farms. How-ever, qualifying the effects of commercial wind farms on a local scale and the cumulative impacts of different uses of the sea on the environment at the scale of the entire coastline remains a major research challenge into which DRACCAR is set to provide insight. In the long term, this programme will also help to optimise wind turbine design and to build a permanent coastal observation network. Under this shared banner, three R&D projects are currently in progress: DRACCAR-MMERMAID, DRACCAR-NEMO and DRACCAR-COBHYS.

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The DRACCAR-MMERMAID project

This project, launched in September 2023, aims to provide an integrated framework of innovative monitoring methods for effective and relevant environmental impact assessments, based on cutting-edge technologies and methodological developments. The main expected results are:

- Better knowledge of marine megafauna ecology in the vicinity of an offshore wind farm under construction,
- Development of a continuous *in situ* monitoring approach,
- Integrated and robust sampling strategies to simultaneously monitor several marine megafauna compartments,
- Deep learning algorithms for videos, sonar and passive acoustic data to advance towards automated data processing,
- Advanced ecosystem models at local and regional scales,
- An innovative and replicable approach as a stepping stone towards a national offshore observation network.

Partners
This project is led by France Energies Marines.

Duration: 48 months | **Total budget:** €6,380K
This project receives funding from France Energies Marines and its members and partners, the Normandy region through the ERDF, as well as French State funding managed by the French National Research Agency under the France 2030 investment plan.

It receives funding from the Brittany, Occitanie and SUD Provence-Alpes-Côte d'Azur regions, as well as from the French Directorate General for Energy and Climate (DGEC) through France's National Offshore Wind Observatory.

The DRACCAR-NEMO project

This project, launched in November 2023, aims to develop methodologies and tools for a comprehensive assessment of turbulence at potential offshore wind farm sites. The main expected outcomes of DRACCAR-NEMO are:

- Collection of a new turbulence dataset,
- A methodology for the reconstruction of turbulence from wind lidars (ground-based, floating and scanning),
- Collection of industry-applicable turbulence data from meso-scale modelling,
- Site-specific transfer functions, combining observations and model outputs, to derive offshore information from onshore information.

Partners
This project is led by France Energies Marines and Fraunhofer IWES (Fraunhofer Institute for Wind Energy Systems).

Duration: 30 months | **Budget:** €2,030K
This project receives funding from France Energies Marines and its members and partners, the Normandy region through the ERDF, as well as French State funding managed by the French National Research Agency under the France 2030 investment plan.

It also receives funding from Ifremer, the maritime cluster Pôle Mer Méditerranée and the Occitanie and SUD Provence-Alpes-Côte d'Azur regions.

The DRACCAR-COBHYS project

This project, launched in 2023, aims to study biofouling and benthic species, the behaviour of the mast structure and hydrosedimentary processes. The main expected results are:

- Better knowledge of the reef effect generated by the installation of offshore structures with foundations,
- Precise characterisation of the interactions between currents, sea states and the mast, representative of the phenomena present in an offshore wind farm,
- A detailed understanding of how the met mast can influence the dynamics of the surrounding seabed, and vice versa.

I MOTUS radio telemetry station set up on the mast platform

Partners

This project is led by the Universities of Caen and Le Havre Normandie.

Duration: 60 months | **Total budget:** €5,107K
This project receives funding from France Energies Marines and its members and partners, the Normandy region through the ERDF, as well as French State funding managed by the French National Research Agency under the France 2030 investment plan.
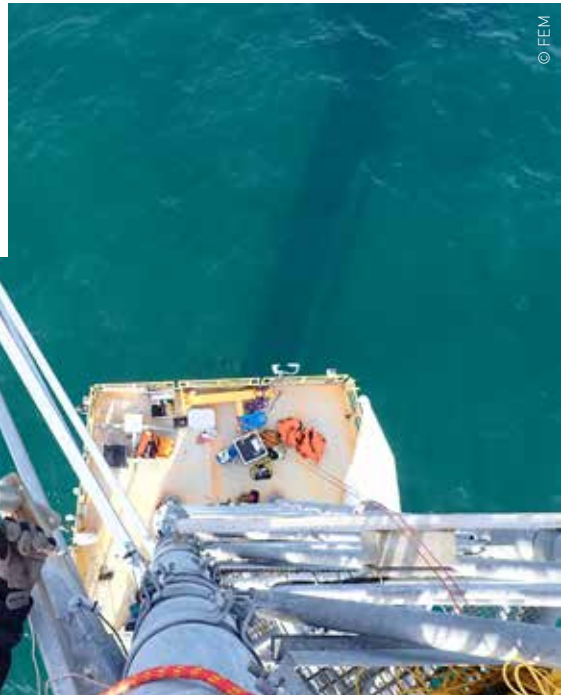
I Installing an anemometer on the mast off Fécamp

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3 QUESTIONS for...
Dominique Clorennec

Chief Scientist, Quiet Oceans

What is Quiet Oceans?

Quiet Oceans is an environmental consultancy set up in 2010. It specialises in assessing the effects of underwater noise on marine fauna and proposing reduction measures. Underwater noise is generated by human activities such as construction work and maritime traffic. Quiet Oceans is involved in the upstream project phase during impact studies and initial environmental assessments, then in the construction phase to monitor and apply site rules aimed at mitigating acoustic risks, and finally during the operational phase. We use noise monitoring systems and marine mammal detection system. We also work in other areas, in particular on the implementation of the Marine Strategy Framework Directive in terms of the assessment of noise levels in territorial waters. For instance, Quiet Oceans has developed an online platform called Quonops Online Services for mapping and forecasting underwater noise in order to meet the needs of government departments and industry.

What role do you play in the DRACCAR-MMERMAID project, of which you are a partner?
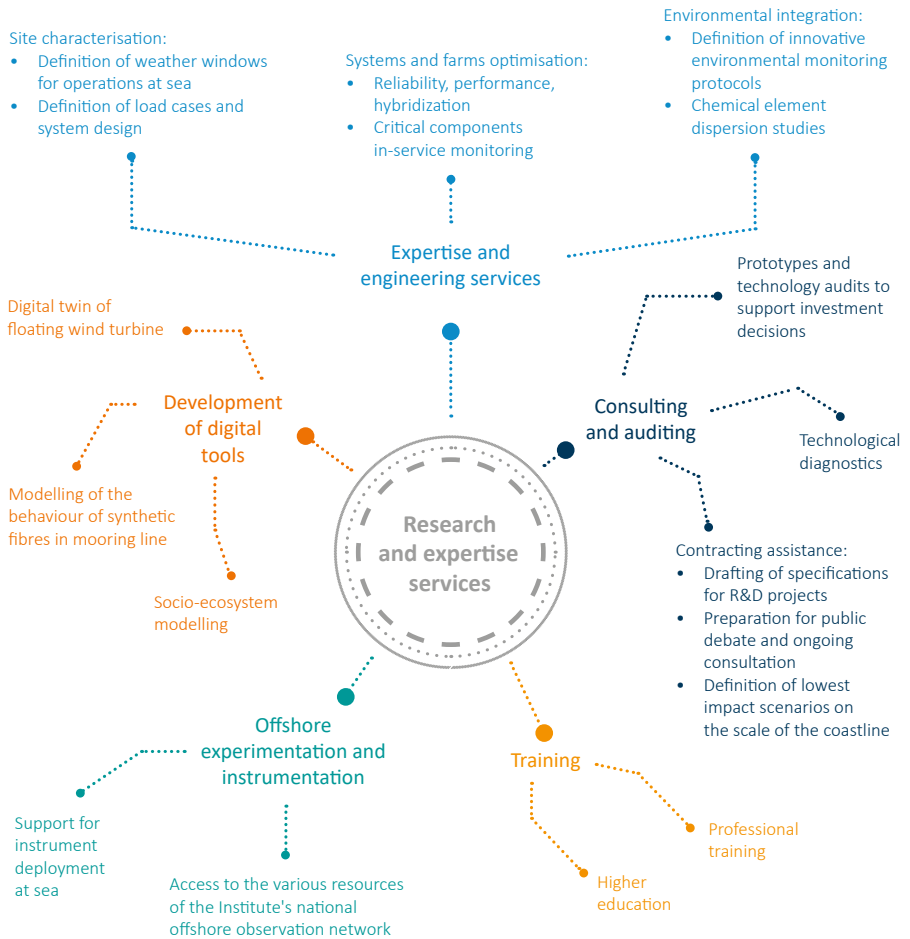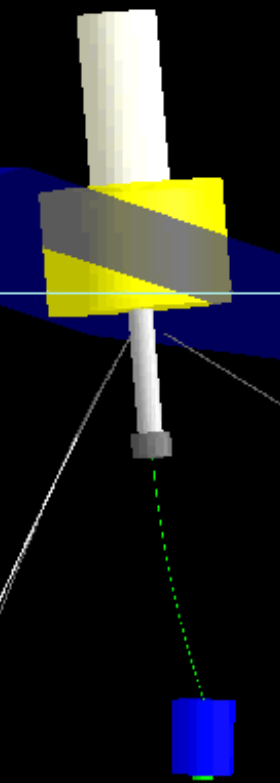
Our primary role is to provide expertise on the acquisition of underwater noise data at the Fécamp met mast, near which several hydrophones are deployed. In passive acoustics, it is not always straightforward to obtain high quality sound. Many parasite sounds can interfere with the signal and mask useful information. It is therefore very important to have good knowledge of the acquisition chain and the environment in which the system is deployed, so as to be able to capture the full chorus of underwater sound, from the low frequencies of vessels and whales up to the high frequencies of porpoises. Our second role in the project is to provide statistical noise mapping for the Channel area, including the environmental contribution (wind, waves), maritime traffic and wind farms in operation. This underwater noise data is integrated into an ecosystem model developed as part of the project, in order to assess the cumulative effects, at the scale of the coastline, on ecosystem functioning. This new approach will lead to a better understanding of the importance of human activities, and in particular the effects of offshore renewable energy, through the underwater noise component in the evolution of the ecosystem.

What does Quiet Oceans have to gain from this project?

We often tend to work on individual projects. The DRACCAR-MMERMAID research project gives us the opportunity to be involved in studying cumulative effects at the scale of an entire coastline. It is also the chance for us to contribute to the integration of a new factor, that of underwater noise, in the ecological assessment of the Channel, which is a game-changer. Additionally, thanks to the cross-disciplinary nature of the project, the partners mutually benefit from learning about the topics studied and instruments used by the other partners.

07

RESEARCH AND EXPERTISE SERVICES

With a 80-strong multidisciplinary team and experience in over 80 R&D projects, France Energies Marines offers research and expertise services in line with the needs of private and public sector stakeholders. Positioned as a key partner, the Institute supports the sector at each stage in the life cycle of an offshore wind project, from planning and development to construction, operation, installation and decommissioning.

Site characterisation:
- Definition of weather windows for operations at sea
- Definition of load cases and system design

Systems and farms optimisation:
- Reliability, performance, hybridization
- Critical components in-service monitoring

Environmental integration:
- Definition of innovative environmental monitoring protocols
- Chemical element dispersion studies

Expertise and engineering services

Prototypes and technology audits to support investment decisions

Digital twin of floating wind turbine

Development of digital tools

Consulting and auditing

Technological diagnostics

Modelling of the behaviour of synthetic fibres in mooring line

Research and expertise services

Contracting assistance:
- Drafting of specifications for R&D projects
- Preparation for public debate and ongoing consultation
- Definition of lowest impact scenarios on the scale of the coastline

Socio-ecosystem modelling

Offshore experimentation and instrumentation

Training

Support for instrument deployment at sea

Access to the various resources of the Institute's national offshore observation network

Higher education

Professional training

Service offering description

France Energies Marines provides a range of research and expertise services, based on an in-depth analysis of the market and the skills developed through its R&D programmes.

Its strength lies in the scientific excellence and innovative mindset that drive its team, leading to the development of new technologies and methodologies to meet the current and future challenges of offshore wind energy. The Institute brings together and coordinates an array of scientific expertise and resources to validate standards from laboratory scale up to full-scale operational conditions and to bring to life the innovations needed to support the sector.

This offering covers five areas: consulting and auditing, expertise and engineering services, development of digital tools, experimentation at sea and instrumentation, as well as training. Through this organisation, the Institute is able to provide bespoke solutions tailored to each project stage.

The Institute is actively involved with the various stakeholders in the value chain, specifically responding to their needs. Our flagship services include site characterisation, which is essential for assessing the offshore wind potential, the definition of real-time monitoring strategies for floating wind turbines, and the design and optimisation of floating systems.

Consulting and auditing

France Energies Marines supports investors in their strategic decision-making process by offering in-depth concept and technology audits. The Institute also carries out technological diagnostics for wind farm and wind technology developers, assessing the technical viability of projects, identifying potential challenges and proposing innovative solutions to overcome them.

The Institute also provides project management assistance to government services and farm developers, acting as a technical interface on specialised issues. Whether for drafting specifications for R&D projects, providing scientific support to prepare public debates and ongoing consultation, or offering support for maritime planning at the scale of the coastline, the Institute builds on its multidisciplinary expertise to ensure the success of the project while minimising its environmental impact.

Flying wildlife monitoring

The French Biodiversity Agency (OFB) chose France Energies Marines to be responsible for overall coordination of the MIGRATLANE programme, in cooperation with the French Natural History Museum. With an overall budget of €9M, this programme brings together around fifteen different partners (scientific laboratories, research institutes, consultancies and associations) which are implementing actions to gain precise knowledge of the use of the Channel-Atlantic area by flying wildlife (seabirds, migratory terrestrial birds and bats), against a backdrop of increasing maritime uses, particularly offshore wind energy.

In addition to the day-to-day management of the programme, France Energies Marines has installed bird and bat acoustic recorders on the Fécamp met mast, to help CESCO (Centre d'Ecologie et des Sciences de la Conservation) to complete the network of acoustic monitoring sites located on the coast and at sea, throughout the study area.

Expertise and engineering services

France Energies Marines provides expertise and engineering services for the various aspects of its R&D programmes.

In terms of site characterisation, the Institute can perform coupled modelling of wind, waves and currents to determine the weather windows for offshore operations. Furthermore, the Institute has expertise in the characterisation of breaking and impact waves, and develops methods for rationally defining the sea states to be considered for designing floating wind turbines.

France Energies Marines is also highly competent in terms of system optimisation (reliability, yield, hybridisation), operation and maintenance, and in-service monitoring of critical components (real-time health status, anticipation of maintenance, reassessment of service life). The Institute works on innovative mooring technologies and the in-service monitoring of dynamic subsea cables and floating wind turbines.

Finally, the Institute also focuses on the environmental and societal integration of offshore renewable energy systems by developing innovative monitoring protocols for farm developers and consultancies, as well as by studying hydrodynamic conditions and the dispersion of chemical elements.

COMPLETED IN 2023

Study of the potential of bottom-fixed and floating wind energy in Brittany

On behalf of Bretagne Développement Innovation, France Energies Marines carried out a study into the potential of bottom-fixed and floating wind energy in Brittany by 2034 and 2050.

In order to meet the 45 GW offshore wind target by 2050, the French National Commission for Public Debate (CNDP) is organising debates for each coastline. The Institute was tasked with carrying out a specific study on the areas where offshore wind farms could potentially be installed along the coast of Brittany. The work involved mapping out macro-zones for the potential installation of offshore wind farms, taking into account regulatory, technical, economic, human and environmental sensitivity criteria. This study was completed with feedback on the impact on tourism and the landscape sensitivity of the potential zones identified. The contribution of the Institute's cross-disciplinary and complementary areas of expertise was pivotal to the successful completion of this study.

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Offshore wind energy and the environment

On behalf of French Syndicate for Renewables (SER) and France Renouvelables, the Institute produced a review, based on a 2022 bibliography, of the potential effects of wind farm development on the environment and measures to mitigate these effects in France and abroad.

Alongside this literature review, a public booklet composed of 13 fact sheets was produced.

These fact sheets are designed to provide an overview of the various pressures of offshore wind energy on the environment and to describe the main causes, the potential associated effects, the main species affected and concrete examples of avoidance, mitigation and compensation measures implemented. In each fact sheet, feedback from pilot sites or commercial wind farms is outlined.

FICHES SYNTHÉTIQUES

2023

LES EFFETS DE L'ÉOLIEN EN MER SUR L'ENVIRONNEMENT

Understanding coastal change

As part of the New-Wave project, France Energies Marines was called upon to contribute its expertise in stereo-video systems. This project, selected under the ISBlue Emergence 2023 call for projects and coordinated by the Université de Bretagne Occidentale, aims to boost the understanding of coastal change by applying innovative methods to characterise the spatio-temporal variability of hydrodynamic forcing over complex bathymetries. The Institute conducted a research assignment on the deployment of the stereo-video system, processing of the data acquired and comparison with data from other instruments in order to validate this original four-dimensional sea state characterisation method.

Development of numerical tools

The development of numerical tools is critical in order to tackle the challenges posed by the change of scale inherent to offshore wind development. This requires standards to evolve and models to be validated so as to guarantee the reliability and profitability of energy systems.

Within this context, the Institute develops custom-made numerical tools tailored to the needs of its clients, building on solid experience forged through many R&D projects. Among its many achievements, the Institute has built a digital twin of a floating wind turbine, combining smart digital networks with input data from sensors coupled with digital simulations, with a view to reducing uncertainties over the fatigue life of components and thus facilitating the operation of commercial wind farms. The team at France Energies Marines has also been working for several years on the non-linear behaviour of synthetic fibres used in mooring lines, in particular nylon.

The Institute has developed a visco-elasto-plastic rheological model specific to this fibre and a new behaviour law to model nylon during design phases.

Thanks to its expertise and strong academic partnerships, the Institute is able to assess the influence of offshore wind projects on the socio-ecosystem using ecosystem modelling approaches.

Offshore experimentation and instrumentation

France Energies Marines is committed to including experimental components in the R&D projects it conducts. The Institute offers support for the deployment of offshore instrumentation such as lidar, current profilers and biofouling monitoring systems. In addition, it can offer access to its national offshore observation network, which includes a multi-instrumented met mast off Fécamp, as well as to its offshore platform for testing innovative moorings and sensors.

Training

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 2023, most of the training sessions 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 prepared by our lecturers are richly illustrated with diagrams and videos. Their content is based on past experience of various R&D projects carried out over the last ten years.

Sea states

Naval officer course
2nd year - VAGM module

Power electronics applied to ORE

Masters 2

Evaluation of offshore renewable resources

European Master
in Renewable Energy

ORE course

EI course
4th year

Environmental integration of ORE

Masters 2 in marine
and coastal sciences

IMEO & GM Masters

GEE MAEVA GRETE Masters

Multidisciplinary approaches in the marine environment

Masters & PhD

Introduction to offshore renewable energy technologies

Continuing professional
development

08

EXPERT PANELS AND NETWORKS

France Energies Marines is greatly involved in various cross-cutting initiatives with a common goal of supporting the development of offshore wind through research.

National support for the sector's development

France Energies Marines works with regional authorities and the associated bodies dedicated to the marine environment as the sector's technical advisor during consultations, and takes part in various panels relating to strategic orientations, future international standards and the environment. The Institute contributes to public debates by providing insight and presenting research results. It is also involved in networks dedicated to facilitating and coordinating research, development and innovation.

Support for regional authorities

Commission Régionale Mer et Littoral, Assemblée Régionale Mer et Littoral, Conseil Maritime de Façade Méditerranée, Parlement de la Mer

Participation in expert panels

Working groups: IUCN France's renewable energy and biodiversity committee, SER's biodiversity working group, France Renouvelables' environment working group, Open-C Foundation's high-power test site

SIG steering committees: *Eolien en mer, Eoliennes en mer de Yeu et de Noirmoutier*

Contribution to public debates

Call for Tender n°4 Normandy, Call for Tender n°5 South Brittany, Call for Tender n°6 Mediterranean, La Mer en Débat

Involvement in stakeholder networks

New Energy Systems Sector Strategy Committee (CSF), Sea Industry Sector Strategy Committee (CSF), New Generation Offshore Industry Roadmap, Open-C Foundation, FIT Association, Campus Mondial de la Mer, maritime clusters

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Coordination of expert panels: COME3T

France Energies Marines coordinates the COME3T initiative, whose purpose is to put environmental and societal questions to a panel of neutral and independent experts. The questions addressed are based on issues identified by the sector as well as public queries. A steering committee, comprising a broad range of public and private stakeholders, selects the scientific topics to be addressed and ensures the neutrality of the expert panels. The experts explore the issue in depth and rank the topic according to how much of a challenge it represents. All the information gathered is summarised in informative bulletins and videos. In 2023, three bulletins were published on electromagnetic fields, galvanic anodes, and the risk of entanglement for marine megafauna. Two videos were produced, one on the effects of wind farms on marine mammals and the other on coastline dynamics.

I Still from the video on interactions between wind farms and marine mammals

Participation in European networks

WindEurope

Since 2022, the Institute has been a member of WindEurope, which brings together over 500 members from across the entire value chain of wind energy in Europe. This association seeks to facilitate national and international policies and initiatives, which strengthen the development of offshore and onshore wind energy markets, infrastructures and technology. Every year, it organises an event combining an exhibition and a programme of conferences, attracting over 12,000 visitors and 500 exhibitors.

I The Institute at the WindEurope event in Bilbao

Common Environmental Assessment Framework - CEAF

France Energies Marines continues to pursue 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. The objective of this network is to support the definition of maritime planning objectives by making recommendations on implementing a common environmental assessment framework.

Ocean Energy Europe - OEE

OEE is a network of ocean energy professionals, representing more than 120 European organisations. France Energies Marines is a member of this pivotal network.

SEETIP Ocean

Coordinated by Ocean Energy Europe, the European project SEETIP Ocean aims to strengthen cooperation and collaboration between the key players in the European ocean energy sector. Within this context, a study was carried out on the involvement of local communities in ocean energy projects in order to identify good practices, gain a better understanding of regulatory frameworks and processes, and make recommendations to anticipate potential conflicts and propose compromise solutions. This work has shown that the challenges of social acceptability lie in the organisation of collective action between project developers and local communities. A summary report was produced and published on the etipocean.eu website.

International reach

IEA Wind TCP, the International Energy Agency's Wind Technological Collaboration Program

Within this programme, France Energies Marines is one of the ambassadors for the WREN project (also known as Task 34), which focuses on the environmental effects of onshore and offshore wind energy. Launched in October 2012, WREN represents 13 European and North American nations. The Institute acts as the French representative among the other project ambassadors, communicating on national progress in wind energy and biodiversity. Within this context, it participates in drafting reports and takes part in plenary sessions aimed at establishing an inventory of scientific knowledge and techniques in the field.

IEA-OES, the International Energy Agency's Ocean Energy Systems Technological Collaboration Program

Through international expertise, the IEA-OES programme aims to promote the viability, uptake and acceptance of ocean energy recovery systems by integrating a sustainable development approach. Factual, independent and collegially developed, the documents produced are intended as a benchmark. France Energies Marines has represented France within the programme since 2016.

The Institute continued its participation as a scientific contributor to OES Environmental, one of IEA-OES' flagship projects, involved in examining the environmental effects of ORE development. This programme brings together 16 nations from all five continents. France Energies Marines staff members participate in the organisation's quarterly analyst meetings, most often held by videoconference.

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FINANCIAL SUMMARY

2023 was another year of strong growth for France Energies Marines thanks to the increasing momentum of offshore wind development. This year's landmark event was the purchase of the met mast located off Fécamp by the Institute from the Eoliennes Offshores des Hautes Falaises company. This offshore infrastructure underpins the DRACCAR sector programme, which is strongly supported by the Normandy region and benefits from a total budget of €13.5M. Nine new research projects were launched, five of which come under the Institute's annual R&D consolidation process and represent a budget of over €13M. In total, in 2023, France Energies Marines committed €13.7M, compared to €8.2M the previous year, representing over 66% growth in commitments. Four new members joined the Institute: Alliance Sorbonne Université, Ecole centrale de Nantes, Iberdrola France and Océanide.

Another important milestone in 2023 was the closing down of the France Energies Marines Association, created in 2012 as a precursor to the Institute for Energy Transition. The last assets were transferred and the accounts have been closed. The General Meeting in November 2023 approved the dissolution of the Association.

The joint-stock company's operating result for 2023 is €186K, down 63% from 2022. Operating income was €7,329K (compared to €7,190K in 2022) and operating expenses represented €7,142K (compared to €6,681K in 2022). The balance sheet total stands at €24,864K, up more than 50% from 2022.
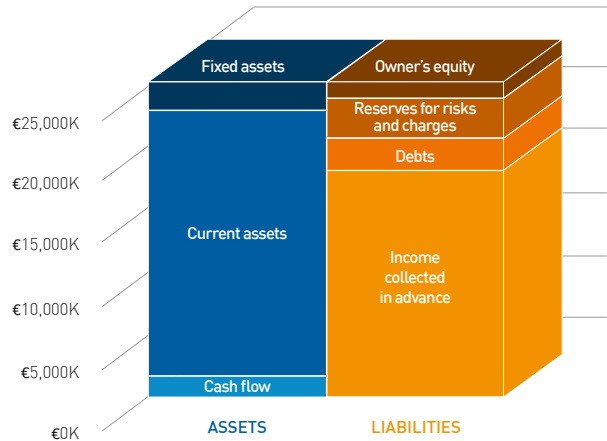
Operating revenues of the joint-stock company in 2023
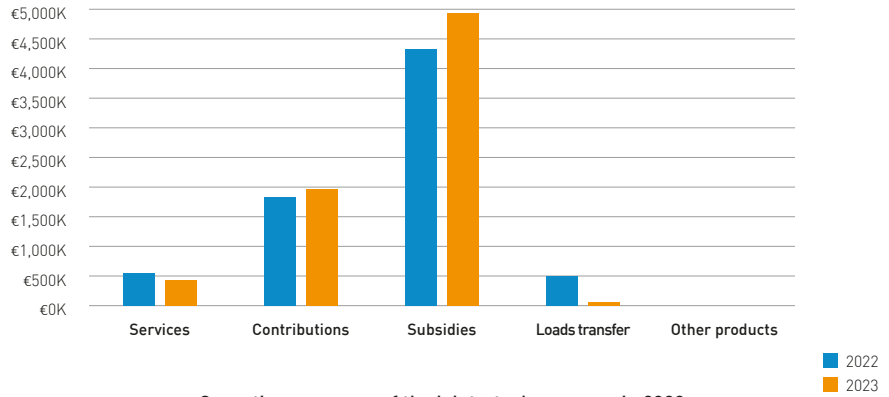
Operating expenses of the joint-stock company in 2023
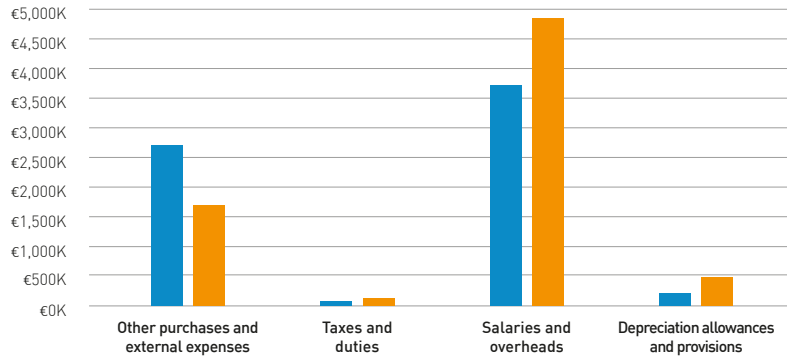
I Joint-stock company income statement for 2023 against 2022

I Joint-stock company balance sheet for 2023

10

OUTLOOK

Offshore wind energy has been confirmed as one of the pillars of France's national energy transition. The stakes are clear and the obstacles known for a full-scale roll-out at the right level of competitiveness, with the potential to boost industrial employment across several regions. With the renewal of its agreement for the period 2025-2030, the Institute seeks to pursue its growth and to drive technological developments in France.

Our activities relating to R&D projects will remain a major focus. Seven projects resulting from the annual consolidation of the Institute's R&D are scheduled to come to a close, eleven will continue and five are due to be launched. Meanwhile, proposals drawn up in 2023 for national and European calls for projects are set to come to fruition in the near future.

The DRACCAR programme, based on the instrumentation of a met mast off Fécamp, is set to continue. Many offshore campaigns are scheduled to install new equipment throughout the year. A second sector programme should be launched in 2024, focusing on the development of technological building blocks for future direct current floating substations.

In terms of transfer, research and expertise services will continue to grow. In complement to this, aspects relating to operating licences and knowledge transfer will continue to be structured. With a view to generating own resources, the industrial transfer aspect is of particular importance in terms of attracting technology companies as members of the Institute. This will involve exploring issues related to transfer vectors and intellectual property issues in depth.

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