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Project Acronym: FLOATECH

Project title: Optimization of floating wind turbines using innovative control techniques and fully coupled open-source engineering tool

Periodic Technical Report

Part B

Period covered by the report: from [01/01/2021] to [30/06/2022]

Periodic report: *[*1st*]*

[1] The term 'project' used in this template equates to an 'action' in certain other Horizon 2020 documentation

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1. Explanation of the work carried out by the beneficiaries and Overview of the progress

FLOATECH is a three-year project (2021 – 2023) in which four institutions and nine industrial companies from across Europe work together towards an increased technical maturity of floating offshore wind turbines (FOWT). This technology has gained interest within academic and also industrial circles due to its potential to exploit offshore sites with high energy potential located at depths that are currently unreachable for fixed bottom offshore wind turbines. Therefore, FOWT will become a key technology for the European Union (EU) to meet the environmental and energy policy goals. Furthermore, due to the global interest in floating wind, research in this field strengthens the leadership role of the EU in this key technology and market of the future. Currently, floating offshore wind (FOW) is still more expensive compared to their bottom-fixed offshore wind (BFOW) counterparts, but given the early stage of its development, FOW could potentially decrease costs at an even greater speed than FBOW has seen during its development.

To achieve this objective, the FLOATECH consortium brings together expertise from leading institutions on each of the key aspects that FOWT combine - aerodynamics, hydrodynamics and control. New control technologies are developed and their overall impact on energy yield, structural trade-offs and costs are analysed in a newly developed software tool with state-of-the-art breaking standards and open-source accessibility. The potential overall impact of the research within FLOATECH on the LCOE of FOWT is quantified at the end of the project.

In the first period from January 2021 to June 2022, the main focus was on the development of the integrated aero-servo-hydro-elastic simulation code QBlade-Ocean, a key tool on which multiple work packages depend upon in period two. Moreover, both novel control strategies were analysed and the results serve as a basis for further experimental campaigns and numerical investigations in the next reporting period. At the same time, the FLOATECH consortium has been active in disseminating the project itself and its scientific results by participating in exhibitions, conferences and the organization of a joint side event with another European project called FLOAWER.

This report marks the end of the first reporting period of FLOATECH and simultaneously represents the half-way point of the project. The global objectives of the project and the work carried out in each of the WPs are detailed further below.

1.1. Objectives

In Annex 1 to the Grant Agreement (GA), five overarching research and innovation objectives were defined. Each of them is presented in this section together with the work that was carried out during this reporting period towards their achievement. The work related to each work package specifically is provided in this report.

1.1.1. Objective 1 – Get a better insight on the physical phenomena taking place in a floating turbine, both in terms of aerodynamics and hydrodynamics

A key requirement in the achievement of Objective 1 was the successful development of the simulation tool QBlade-Ocean in WP1. Advancements of the code have been twofold. First, the implementation of a higher order wake method (Vortex Particle Multi-Level Method - VPML) that surpasses the physical fidelity of comparable packages of open-source software, and allows the simulation of the helical structure of the turbine wake and the modal frequencies that promote its breakdown accurately. Second, hydrostatic and hydrodynamic capabilities are added in a flexible manner, where first- and second-order linear potential flow solvers (LPF) and a Morison equation (ME) solver can be combined, non-linear buoyancy can be selected and explicit mooring lines can be simulated for both flexible and stiff substructures. Thus, higher order hydro- and aerodynamic loads on an arbitrary structure can be simulated and understood. The quantification of improvements towards the state-of-the-art will be the main task of WP2 in which already first results of QBlade-Ocean were validated with experiments and code-to-code comparisons in rather simple load cases. The software was released in open-source after the consortium took part in a three-day workshop in June 2022.

The new experimental software-in-the-loop testing methods will mainly occur in reporting period 2. In the past 18 months the focus lied on the preparation and development of the controller itself, the design of the controller interface for software-in-the-loop experiments and the construction of actuators and experimental models.

The validation for active wave control has begun with an experimental campaign in a wave tank where wave elevation data is captured and serves as a validation database for wave prediction algorithms.

1.1.2. Objective 2 – Model and reduce the uncertainties in the design process by means of proposed simulation approach

The lifting-line method implemented in QBlade-Ocean increases the aerodynamic fidelity considerably in offshore relevant use cases with large and flexible structures that violate key assumptions from blade element momentum (BEM) methods. With the implementation of the VPML method, the physical representability of the wake aerodynamics should further increase. To quantify the improvement, further simulations that focus on that aspect are still to be done.

A thorough uncertainty quantification will be carried out throughout WP2 in the remainder of the project and will be detailed in the final report.

Aside from the development towards high physical accuracy paired with fast computational speed due to thorough parallelization, the graphical-user-interface (GUI) of QBlade-Ocean was improved continuously. The user gets an immediate visual impression of the model, the sea sate and the aerodynamic loads. The GUI simplifies an interactive use of the program and thereby opens the door for young researchers and students to use the software and to learn about all the aspects of FOWT.

1.1.3. Objective 3 – Facilitate the assessment of new technological concepts, techniques and system by high computing resources and dedicated experiments

As the experimental campaigns will be carried out in the second reporting period, this objective remains to be achieved throughout the remainder of the project. The expected outcome however is that the organization of multiple experimental testing campaigns throughout WP3 and WP4 creates experience and knowledge in the setup of complex testing campaigns for FOWT where wave- and wind loads simultaneously are applied. This knowledge will be key if other design concepts are to be investigated in the future.

The device that captures wave elevation data is a radar system that is mounted on the tower of a FOWT. Within FLOATECH such a system was purchased, firstly the device was installed onshore in the St. Nazaire harbour in the beginning of June 2022 to run dry tests. Upon the completion of the dry tests, the radar has now been deployed on the FLOATGEN offshore platform a few weeks afterwards. Thereby, the opportunity to repeat a test previously performed in a wave tank experiment in the free field on a utility scale 2MW turbine on a floating platform is created.

In WP1 efforts have been made to make us of parallelization to decrease simulation runtime. To achieve this, the massive parallelization capabilities of graphics processing units (GPUs) are used through OpenCL (an interface that executes calculations across heterogenous platforms, such as CPUs and GPUs). Where the parallelization on the GPU is not implemented, the simulation tasks are distributed amongst the available central processing units (CPUs) of a given working station through OpenMP (an interface that allows multi-platform shared-memory multiprocessing).

1.1.4. Objective 4 – Increase the future market value of offshore wind energy

The groundwork of this objective has been laid right in the beginning of the project with the successful coupling of the TU Delft controller to a preliminary QBlade-Ocean version. In May 2022 the QBlade-Ocean version was updated to a fully capable version including all the floating offshore functionalities. Thereby, the controller development, validation and application are now ongoing by the end of this period. The application of the controller and the main outcomes regarding the evaluation of increased market value of future offshore wind turbines will be part of the analysis in WP5 which starts in reporting period 2.

1.1.5. Objective 5 – Reduce the LCOE by means of: 1) a performance increase of new machines thanks to the more advanced and predictive simulation tools; 2) innovative control techniques able to maximize the performance during the floating motion

The work in this first reporting period will serve as the evaluation tool, in the case of QBlade-Ocean, and evaluation object, in the case of the control technologies and their influence on energy yield, fatigue, etc., for work package 5 in its analysis of LCOE reduction and performance optimization. Thereby, the focus lied on the development of the tools and technologies so far and only preliminary work towards the achievement of this objective specifically has been done. This focus will switch to the application of the development and the evaluation of its impact in the next and final reporting period.

Throughout the present report, FLOATECH beneficiaries will be addressed by their abbreviations. The abbreviations corresponding to a beneficiary may be found in the table below.

Table 1 - List of FLOATECH beneficiaries.

ABBREVIATION	FULL NAME
TUB	Technische Universität Berlin
Unifi	University of Florence
ECN	École Centrale de Nantes
TU Delft	Delft University of Technology
Seapower	SeaPower SCRL
EURO	Euronovia
Saipem	Saipem SA
BW Ideol	BW Ideol
NO	Next Ocean BV

Annex 1 to the Grant Agreement may be illustrated in the Gantt Chart that is shown in Figure 1. The hatched cells represent delays in the respective work packages. Explanation for the occurrence as well as mitigation plans for those reasonings are listed in below Section 5 of this report.

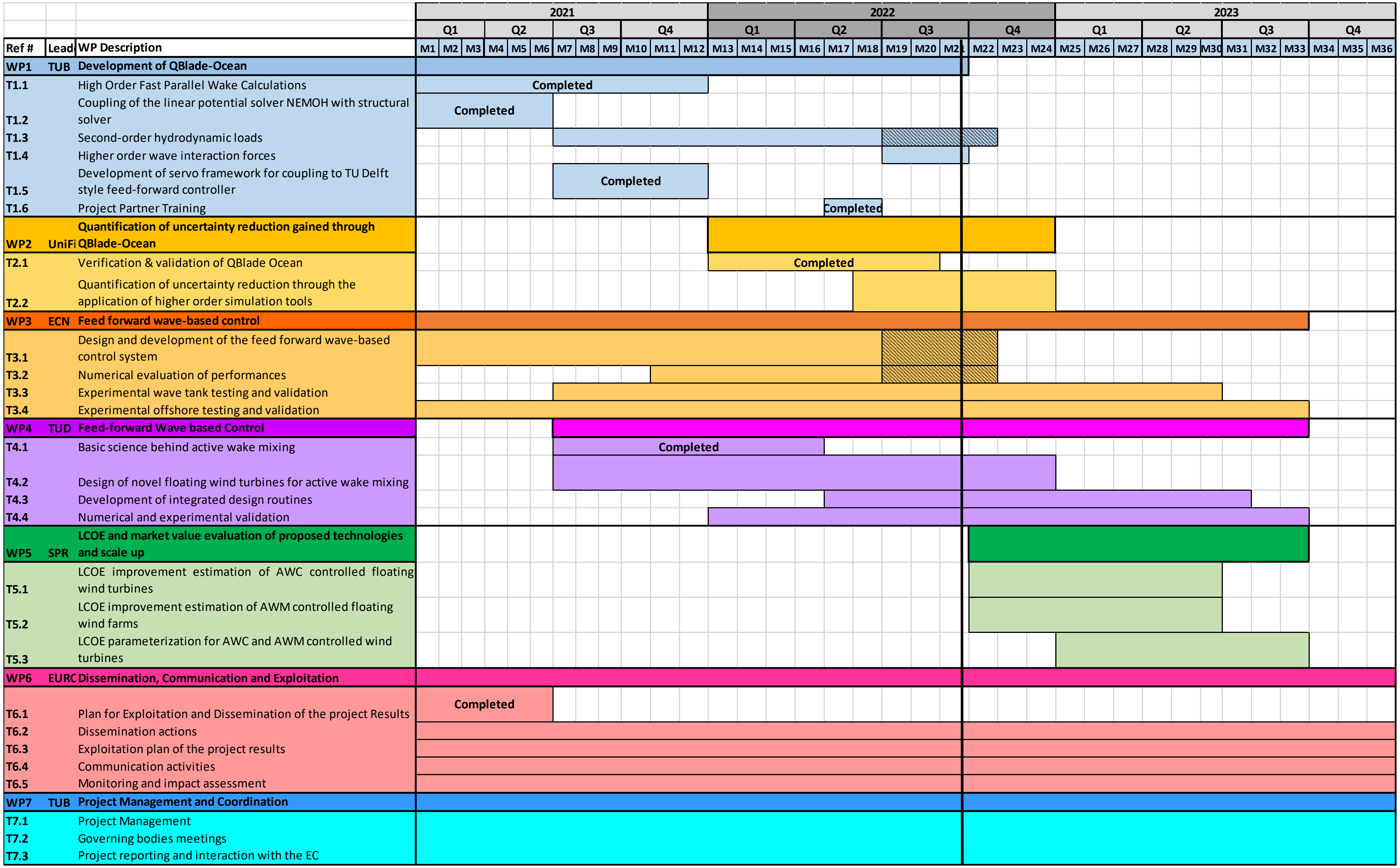

Figure 1 – Gantt Chart of the FLOATECH. The Vertical line represents the current point in time, the hatched cells represent delay in a task.

1.2. *Explanation of the work carried per WP*

1.2.1. Work Package 1 - High order open-source aero-hydroservo- elastic simulation tool (TUB)

The main objective of work package 1 (WP1) is the development of open source software tools for the simulation of floating offshore wind turbines. Pursuant to this objective, WP1 has been structured in a way that key implementation steps can occur in parallel in order to reduce development time. In addition to this objective, the dissemination and communication of the tools is given priority in order to ensure effective uptake of the developed tools into both industry and academia. The task is a collaborative effort between four institutes: TUB - WP lead and main beneficiary, Unifi, ECN and TU Delft.

Three software packages have been developed or coupled within WP1. These are summarised below:

- QBlade: An open source wind turbine simulation suite developed at TUB (https://qblade.org/).
- NEMOH: An open source hydrodynamic potential flow solver developed at ECN (https://lheea.ec-nantes.fr/valorisation/logiciels-et-brevets/nemoh-presentation)
- HOS-Ocean: An open source spectral high-order nonlinear wave field generation tool, developed at ECN (https://github.com/LHEEA/HOS-ocean).

The majority of the development has occurred within QBlade, which has been extended to be able to account for FOWT configurations with numerous modelling options. This extension has appropriately been given the name QBlade-Ocean to reflect the new capabilities of the suite. NEMOH has been developed to allow for the treatment of second order hydrodynamic loads. No development has occurred on the HOS-Ocean code yet, however within WP1 this shall be coupled to QBlade-Ocean to allow an import functionality of high-fidelity wave fields.

WP1 constitutes a foundational building block of the FLOATECH project as the herein developed tools find application not only in the quantification of the impact of higher order design tools on design driving factors in WP2, but also in the validation and development of cutting edge FOWT farm technologies in WP3 & WP4. WP1 is comprised of six tasks, chronologically structured to optimise development potential and dissemination activities. In addition to this**, three key deliverables ensure the timely and effective implementation and communication of the developed software packages. These have already been successfully submitted at the time of submission of this report**. In the following sections the tasks are described in detail to provide an overview of the planned work, completed work, and deviations from the Annex 1 of the grant agreement.

Task 1.1: High Order Fast Parallel Wake Calculations (M1 – M12, TUB)

TUB was the leader of this task which started with the beginning of the project and **was completed within the planned duration of 12 months**. The objective of this task is the development and validation of a high-order hybrid Eulerian-Lagrangian wake model for the treatment of aerodynamics in the wake of a wind turbine. The model makes use of a vortex particle multilevel (VPML) method which applies geometric coarsening to create a low-rank approximation of the particle interactions and thereby greatly reduces the computation expense of spatial integration of the particle influence. This reduces the problem scaling from the unsuitable Order (N^2) to Order (N), making it possible for larger particle sets to be solved with low computational expense. The advantages of the use of vortex particle dynamics is the ability to treat higher-order aerodynamic effects such as vortex stretching and viscous interaction accurately. As these effects often dominate complicated fluid dynamic phenomena in the wake, a broader range of physical problems can be handled as compared to the use of a lower order, vortex filament-based method.

A main application case for the model is wake stability and excitation measures which are under development in WP4. The model has been implemented in the planned time period and extensive validation tests were carried out by comparing the model against other wake models and an experimental rotor. These results have been summarised within deliverable D1.1. This included validation against lower order aerodynamic models under steady flow conditions and validation against the experimental MexNext turbine. Due to the extensive development within WP1 of the hydrodynamic models and corresponding validation work, the full implementation into QBlade-Ocean is still ongoing and it is anticipated that this will be released as a feature of the subsequent release of QBlade.

Task 1.2: Coupling of the linear potential solver NEMOH with structural solver (M1 – M6, TUB)

The primary objective of this task is the development of a FOWT platform module within QBlade-Ocean for hydrodynamic calculations and its coupling to the linear potential flow hydrodynamics solver NEMOH. The task was led by TUB and was completed within the planned time period (M1 and M6). These separate subtasks are detailed below.

For purposes of adaptability, validation, and extendibility, numerous hydrodynamic models were incorporated into QBlade-Ocean. Furthermore, for future additions to the software, such as the import of external wave fields (from e.g. HOS-Ocean), the framework needed to be prepared in a flexible way to ensure that minimal implementation difficulties would be encountered in the aforementioned tasks. These tasks represented a significant implementation workload. The validation of the models took place in the time period directly following the preparation for deliverable D1.2, which was delivered in M12. As a range of comparison models were chosen, the validation tasks and documentation also required a significant effort. The current FOWT platform hydrodynamics module of QBlade-Ocean has the ability to define arbitrary submerged members and apply a full-Morison approach to the treatment of hydrodynamic loads due to motion and incident wavefields. A module has also been prepared which allows for the import of hydrodynamic datasets from potential flow solvers for single or multiple bodies and fully general definition of load application points. Numerous buoyancy force options are available. The platform structural hydrodynamic definition is conveniently defined through text-based input files which can be specified either within or externally from QBlade-Ocean.

It was originally envisioned that a full (loose) dynamic coupling between QBlade-Ocean and NEMOH would occur. It was however decided relatively early in the project that the inability of NEMOH to handle structural deflections, along with the limited number of practical application cases of this approach made it unfeasible to continue with this plan. Thereby, the coupling should occur with a more general approach whereby NEMOH output files are read as input to the QBlade-Ocean platform hydrodynamic definition, as described above. This allows the hydrodynamic outputs such as the radiation damping and wave excitation forces to be imported into QBlade-Ocean for arbitrary geometries. This development was carried out in M4-M6 and the validation was completed in D1.2.

Task 1.3: Second order hydrodynamic loads (M7 – M18, ECN)

The main objective of this task is the extension of NEMOH to include second order hydrodynamic effects. The task is led by ECN, it started in M7 and is still ongoing. In alignment with the discussion of the previous task, within the context of a full FOWT simulation this is carried out as a pre-processing step and second order hydrodynamic loads are calculated within the hydrodynamic solver as a function of the given wave field. This frequency-dependent second order data is provided in the form of a quadratic transfer function (QTF), which is read in and is used to provide hydrodynamic coefficients for a time-domain simulation. This necessarily involved two steps, development of the pre-processor and development of the time-domain solver.

The pre-processing step occurs within NEMOH and this constitutes the majority of the development work carried out within this task. The solver has been implemented within NEMOH and extensive validation has been carried out. The results have been published in a conference publication (publication). The developmental work has thus been carried out, however preparation for public dissemination occurs within a new release version of the software NEMOH. This requires documentation and the generation of a validation data set.

The time-domain solver is part of the hydrodynamic module of QBlade-Ocean and has been implemented. It has been agreed upon that NEMOH output files formats for the QTFs will be identical to those of the widely used hydrodynamic software WAMIT. With existing template input files for known validation cases in academia, the import functionality could independently be implemented within QBlade. This furthermore allowed for the validation of second order hydrodynamic load calculations within QBlade. This was carried out in D1.2.

Task 1.4: Higher order wave interaction forces (M19 – M21, ECN)

The main objective of this task is the coupling of the open-source wave generation software HOS-Ocean with QBlade-Ocean. The task is led by ECN and starts just after the first reporting period ends in M19. A clear framework for this has been established between the participating partners at TUB and ECN and the development work is required from both groups. The development of a compiled *.dll* library for linking to QBlade-Ocean must be carried out by ECN. Following this, the interface for importing wave field within QBlade-Ocean from HOS-Ocean will be implemented, which allows for simple specification of the wavefield within the QBlade-Ocean graphical user interface (GUI). The points made in the project plan regarding strip theory modelling of the mooring and spatial and temporal integration scheme were carried out as part of Task 1.2. Validation tests will be carried out to ensure correct wave field input is occurring within QBlade-Ocean. The work is tentatively expected to be complete by M22.

Task 1.5: Development of servo framework for coupling to TU Delft style feed-forward controller (M7 – M12, TU Delft)

The main objective of this task is the development of a framework which enables controller design within QBlade-Ocean for the feed-forward wave control as will be investigated within WP3. The task was led by TUB and was completed within the planned time period (M7 and M12). It was originally envisioned that the framework of QBlade-Ocean would allow for linearization of the entire operating system as is possible in the open-source wind turbine simulation suite OpenFAST. In the early phases of development however, it was established that the implementation of such a model was not feasible due to the loosely-coupled framework and general code structure employed within QBlade-Ocean. As a result, it was agreed that a suitable path forward would be to carry out controller design through linearization with a numerical twin of the QBlade-generated model within OpenFAST. These controllers can then be tested within QBlade-Ocean with an appropriate interface which practically acts to provide the controller with forward-time wave information. The interface functions by exploiting additional array data passed between turbine model and controller model at each command step from the turbine controller. This interface has been implemented and controller design planned for WP3 is underway.

Task 1.6: Project partner training (M17 – M18, TUB)

The final task for WP1 is the project partner training for QBlade-Ocean. The training was organized by TUB and carried out during three days at the end of M18 (22nd – 24th of June). The objective of this task was the dissemination of QBlade-Ocean along with a public workshop to encourage use of the model within academia and industry. In addition, a comprehensive online documentation was prepared which gives users a simple overview of the implemented functionalities, the underlying theory and a user guide for preparing and understanding simulations of FOWT within QBlade-Ocean. The event was held successfully and provided an excellent platform for the dissemination and representation of the work carried out in WP1.

A devoted website for the dissemination, communication and forum of QBlade-Ocean has been prepared for the workshop and subsequent use of QBlade. The online documentation was prepared between M14 and M17 with the python-based documentation generator sphinx. It is accessible through the QBlade website hosted page (QBlade documentation).

Deliverables completed:	D1.1 Technical Report: Hybrid Eulerian- Lagrangian Aerodynamic Model (TUB) The Implementation of hybrid Eulerian-Lagrangian flow solver with multilevel method and coupling of the solver to

	QBlade-ocean is achieved and documented. Parallelization of flow solver and demonstration of calculation with GPU acceleration has been carried out. D1.2 Technical Report: Higher Order Hydroelastic Module M12 (TUB) The higher Order hydroelastic module has been integrated and validated. D1.3 Training Manual, Project Partner Workshop and Public Dissemination M18 (TUB) A training workshop hosted by TUB and ECN for the project partners for use of the software will be carried out. A user manual and set of exemplary use cases shall be provided and the partners trained in the use of the software. A test case databank and code repository is made available through the FLOTECH website.
Deliverables passed due date:	There were no delays in the submission of deliverables in this reporting period
Milestones completed:	MS1 - Coupling of NEMOH (to QBlade) MS2 – Completion of Hydroelastic Solver (in QBlade)
Milestones passed due date:	There were no delays in the achievement of the milestones

1.2.2. Work Package 2 - Quantification of uncertainty reduction gained through QBlade-Ocean (Unifi)

Work Package 2 (WP2) comprises of two subtasks: Task 2.1 with the objective of globally validating QBlade-Ocean with comparison to experimental data and other state of the art codes, and Task 2.2 with the objective of quantifying potential improvements and impact of the high-fidelity models implemented in QBlade-Ocean. Work Package 2 started in M13 and ends in M24 with a total duration of 1 year. Task 2.1 is scheduled to end in M20.

The numerical tools that are used in WP2 are QBlade-Ocean, OpenFAST v3.0.0 (OF) and DeepLines Wind (DL).

The partners involved in WP2 are: Unifi - work package lead, TUB, ECN, Seapower and Saipem.

The following sections, detailing the work conducted so far in WP2, are structured as follows: firstly, the work carried out so far within Task 2.1 will be explained. Secondly, a brief explanation of the numerical models used for validation (**full detail in Deliverable 2.1, submitted in M14**), followed by a description of the tests that were performed and the contributions to this part of the work package by each institution is given. The following section then describes the work done for Task 2.2. Firstly, two main preliminary actions are described: the definition of a Design Load Case (DLC) basis for code-to-code comparison and the definition of met-ocean conditions suitable for such comparisons. This is followed by the description of a set of minor preliminary work that was conducted, no less important for the continuing of the work package. Finally, partner contribution in Task 2.2 are highlighted.

Task 2.1 - Verification & validation of QBlade-Ocean

In Task 2.1, three numerical models of Floating Offshore Wind Turbines have been set-up by the various partners in different engineering tools. The three models differ in rated power and floater geometries: the 10 MW SOFTWIND turbine mounted on a spar floater, the 5 MW OC5 turbine mounted on a semi-submersible floater and the DTU 10 MW Reference Wind Turbine mounted on the Hexafloat floater. Each model represents a different approach of FOWT technology, and it is essential that the aero-servo-hydro-elastic capabilities of QBlade-Ocean are verified with a broad range of designs to ensure that the software can be used for all types of FOWTs. Deliverable 2.1 contains a detailed description of the numerical models, however, for the sake of completeness, a brief description of each model will be provided herein.

The first model is the DTU 10MW SOFTWIND model, a FOWT that was built and tested by ECN. Within the FLOATECH project, this wind turbine model is analysed with QB, OF and DL. The experimental setup of the SOFTWIND turbine consisted of a thrust actuator with a software-in-the-loop aerodynamic model coupled to a physical tower and floater. The actuator force is determined numerically by a FAST v7-Aerodyn14 aerodynamic model based on the incoming wind speed and the platform and actuator’s motions, as measured in real-time on the experimental model. The rotor of the SOFTWIND 10 MW FOWT is based on the DTU 10 MW reference wind turbine. The detailed aerodynamic definition is provided in Deliverable 2.1. The nacelle and tower are modelled so that the total mass and centre of gravity of the RNA match the definition of the scaled model. The tower is made of an aluminium rod and the distributed parameters were obtained by appropriately scaling the density and Young’s modulus of the aluminium rod used in the experiments. In addition, the stiffness was tuned to match the eigenfrequencies of the FOWT. Within the numerical tools, the substructure is modelled as a rigid body using the linear potential flow with an additional Morison drag (LPMD) approach. The hydrodynamic radiation and diffraction coefficients were obtained from calculations using the software NEMOH. The mooring system of the SOFTWIND FOWT is made of chains connected in a delta-connection configuration. The QB model of the SOFTWIND FOWT is publicly available at following location:

https://doi.org/10.5281/zenodo.6397358

The second numerical model consists of the DTU 10MW Reference Wind Turbine rotor mounted on top of Saipem’s Hexafloat substructure. In this document, it will be named the Hexafloat 10 MW FOWT model. Within the FLOATECH project, this model is analysed in QB and DL. The blade aerodynamic and structural definition are the same of those of the DTU

10MW SOFTWIND turbine. The nacelle and tower properties are defined by DTU in (Bak, et al., 2013) and are specified fully in Deliverable 2.1 (Perez-Becker & Behrens de Luna, 2022). The floating substructure consists of a floating hexagonal structure and a counterweight linked together by six tendons. The elements of the substructure are modelled as either flexible or rigid elements and the tendons as cable elements. The hydrodynamic forces are calculated using the Morison equation approach. The mooring system of the Hexafloat FOWT is made of three chains connected to the floater. The QB model of Hexafloat FOWT is publicly available at following location:

https://doi.org/10.5281/zenodo.6397313

The third model is the NREL 5MW OC5 model that is a FOWT analysed in the Offshore Code Comparison Collaboration, Continued, with Correlation (OC5) project (Robertson A. e., 2017) The floating substructure is of semisubmersible type with close similarities to the floater analysed within Phase II of OC4 (Robertson A. e.). The turbine mounted on the floater is the MARIN stock wind turbine (MSWT) described in (Goupee, et al.), a model-scale version of the NREL5-MW reference wind turbine (J., Butterfield, Musial, & Scott, 2009) developed by the Maritime Research Institute Netherlands (MARIN) in 2013 (A., Jonkman, Wendt, Goupee, & Dagher) with the objective of matching the thrust coefficient of the full-scale NREL 5MW model as well as possible. The assembled FOWT model was analysed experimentally in the MARIN offshore wave basin in a 1/50th scale. Both the model and the results are scaled up to full scale, which is why the full-scale turbine properties are used to build the model within FLOATECH. Within the FLOATECH project, this model is analysed in QB and OF. The rotor properties of the OC5 FOWT are based on the blade design detailed in (Goupee, et al.) and (A., Jonkman, Wendt, Goupee, & Dagher). The AG04 airfoil defines the aerodynamic behaviour along the entire span of the blade, aside from the cylindrical root sections. The blade may be treated as a stiff structure apart from the cylindrical sections. The nacelle and tower of the up-scaled OC5-FOWT were modelled in accordance with the information provided in (A., Jonkman, Wendt, Goupee, & Dagher). The tower is made of two sections of hollow aluminium rods. In order to match the mass of the measurements cables that are present in the experiments, weight is added to specific tower sections in each numerical model, depending on the specific capabilities of each model. To approximate the documented tower eigenfrequencies, the stiffness of the tower was scaled by the factor 0.75. The detailed geometry of the OC5-definition of the substructure is also given in (A., Jonkman, Wendt, Goupee, & Dagher). As with the SOFTWIND platform, the substructure is modelled as a rigid body using the LPMD approach (Saverin, et al., 2022). The hydrodynamic radiation and diffraction coefficients were obtained from publicly available calculations with the software WAMIT (WAMIT Inc.). The mooring system of the OC5-DeepCwind semisubmersible consists of three catenary mooring lines spread equidistantly around the Z-axis with one of the mooring line being aligned with the X-axis of the platform (A., Jonkman, Wendt, Goupee, & Dagher). The QB model of OC5 FOWT is publicly available at following location:

https://doi.org/10.5281/zenodo.6397352

For each of the three models the following sets of tests are performed:

1. Static-equilibrium tests: this is an important first step to ensure that the model mass properties (overall mass and CoG) and the mooring system are defined properly.

2. Free-decay tests: the objective of these tests is to ensure that system dynamics in terms of natural frequencies and damping are captured properly by the numerical models.

3. Aerodynamic comparisons: these tests are generally conducted with no floating platform. Focus is generally put on ensuring rotor thrust is adequately captured by the numerical models in study.

4. Regular waves test with or without constant wind: these tests are used to validate the hydrodynamic models in QB. In a regular wave test, it is in fact straightforward to notice any discrepancies in wave-induced platform excitation both in terms of phase and amplitude of the response.

5. Irregular waves test without wind: these tests are used to validate the global hydrodynamic response of the numerical models.

6. Irregular waves and wind tests: this final set of tests constitutes the "full validation" of the system in terms of global coupled response to turbulent wind inflow and irregular wave spectra.

Results from these sets of tests for each model will be discussed in Deliverable 2.2 (M20).

Contributions of each partner in Task 2.1:

1. TUB: Set-up and calculations of QB models of DTU 10MW SOFTWIND, DTU 10MW Hexafloat and NREL 5MW OC5 models. Collaborated on interpretation of results for all models.
2. UNIFI: Set-up and calculations of OF models of DTU 10MW SOFTWIND and NREL 5MW OC5. Definition of the test list. Collaborated on interpretation of results for all models.
3. ECN: Provided data from DTU 10MW SOFTWIND experimental campaign. Provided support in exploitation of SOFTWIND experimental results. Provided support in set-up of DTU 10MW SOFTWIND numerical models. Collaborated on interpretation of results for all models.
4. Saipem: Set-up and calculations of DL models of DTU 10MW SOFTWIND, DTU 10MW Hexafloat. Collaborated on interpretation of results for all models.

<u>Task 2.2 - Quantification of uncertainty reduction through the application of higher order simulation tools</u>

Task 2.2 has officially just started at the time of writing of this report, however some necessary preliminary work has been conducted. The preliminary work can be classified as follows:

1. Definition of a set of Design Load Cases to perform code-to-code comparisons. The number of DLCs and consequently the total number of simulations were chosen as a trade-off between:
    1. representation of a wide variety of wind and wave conditions in order to highlight the differences between the codes;
    2. computational effort. A set of DLCs that are significant for fatigue and ultimate loading of main turbine components (blades, yaw bearing, tower, moorings) are selected based on consultation with the work package partners and a literature survey (Jonkman & Buhl, 2007) (Haid, et al.). The final selection is shown in Table 1.
2. Definition of met-ocean conditions for use in Task 2.2. In fact, offshore wind turbines are subject not only to varying wind conditions during their lifetime, but also sea conditions. Therefore, in addition to wind speed, other sea-related quantities need to be considered to characterize a specific installation site. International standards suggest that, at a minimum, significant wave height, peak spectral period and wind/wave misalignment must be considered. Differently from onshore installations, international standards do not prescribe the specific environmental parameters to use in numerical models (such as wind speed, significant wave height, peak spectral period, etc.). These have to be determined from the installation site's long-term distributions to the measured quantities. This task was not initially planned and required additional work from the partners. Since no ready-to-use environmental conditions were available for European sites, this subtask involved:
    1. sourcing the data from an appropriate source; in this case hindcast data from ERA5 (Hersbach, 2022),;
    2. processing the data to obtain a long-term statistical representation of the installation environment;
    3. extracting the required information to define the needed sea states (Normal Sea State (NSS), Severe Sea State (SSS) and Extreme Sea State (ESS)).

Table 2: DLCs for WP2.2

	DLC	wind		waves			tot sims	type
		model	speed	model	height	period		
Power production	**1.2**	NTM	Vin < Vhub < Vout	NSS	Hs min < Hs < Hs max	Tp min < Tp < Tp max	504	F
	1.3	ETM	Vin < Vhub < Vout	NSS	Hs = E[Hs|Vhub]	Tp = E[Tp|Hs]	99	U
	1.4	ECD	Vrated +- 2 m/s	NSS	Hs = E[Hs|Vhub]	Tp = E[Tp|Hs]	6	U
	1.6	NTM	Vin < Vhub < Vout	SSS	Hs,SSS	Tp = E[Tp|Hs]	99	U
Parked	**6.1**	EWM50	V50	ESS	Hs = Hs50	Tp = E[Tp|Hs]	12	U
	6.2	EWM50	V50	ESS	Hs = Hs50	Tp = E[Tp|Hs]	6	U
	6.3	EWM1	V1	ESS	Hs = Hs1	Tp = E[Tp|Hs]	12	U

In addition to the discussed preliminary actions the partners have:

3. Defined wind (Unifi, with support from all partners) and wave fields (Saipem) to be used in WP2.2 ensuring that all partners can use the same input environmental conditions
4. Defined the post-processing toolchain and necessary conversion tools to ensure format compatibility between codes and that the same post-processing tool can be used across all codes (Unifi, TUB)
5. Tested the post-processing toolchain (Unifi, Seapower)

Contributions of each partner in Task 2.2:

1. Unifi (with support from TUB): Researched defined and processed environmental timeseries data to obtain a long-term representation of an EU installation site. Collaborated on definition of DLC list, wind fields and wave fields to use. Defined and tested the post-processing toolchain (with support from TUB, Seapower).
2. TUB: Supported the definition of EU installation site environmental conditions, wind fields, wave fields and definition of DLC list.
3. Saipem: Supported the definition of EU installation site environmental conditions, wind fields and definition of DLC list. Created wave fields for all partners to use in WP2.2.

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Deliverables completed:	D2.1 – Aero-hydro-elastic model definition (M15) A validation report of the new integrated aero-hydro-servo-elastic simulation framework QBlade-Ocean has been created.
Deliverables passed due date:	There were no delays in the submission of deliverables in this reporting period
Milestones completed:	MS3 - Aero-hydro-elastic model database (M15)
Milestones passed due date:	There were no delays in the achievement of the milestones

1.2.3. Work Package 3 – Feed forward wave-based control (ECN)

WP3 focuses on the development and experimental validation of a new technology named Active wave-based control (AWC) for FOWTs. Many of the wind conditions to which FOWTs are exposed are a decisive factor in both, turbine loads and energy yield, as is the sea-state of the environment. This influences greatly the motion and control strategy of the floater and therewith the ability of the floater to capture maximum energy. This technology will combine an open-source feed forward control algorithm and a wave sensing system to achieve wave-based control in floating wind turbines. Deterministic wave prediction and anticipation of induced platform motions are exploited through an ad-hoc pitch controller enhancing the ability of the generator to mitigate platform motions and loads induced by waves, while ensuring fatigue loads from the new feed forward controller are within admissible thresholds.

For development and optimization of the technology both QBlade-Ocean from WP1 and OpenFAST are used in this WP. TU Delft has been developing the control methodology enabling the implementation of the feed-forward wave control (FFW). This is occurring in collaboration with TUB in order to ensure that the controller input/output interface of QBlade-Ocean allows for real-time controller testing and with ECN for the proper accounting of wave information into the controller. The interface to sensing equipment necessary for wave detection along with wave evolution modelling and prediction is carried out by the team at ECN. ECN has carried out one of three laboratory scale tests on the method, the two remaining are scheduled over the next 12 months. Full scale tests of the sensing equipment developed by NO is now ongoing, the sensor having been properly mounted and integrated to BW Ideol 2MW prototype hosted on ECN's test site.

Task 3.1 Design and development of a feed forward wave-based control system (M1-M18, TU Delft)

The conceptual basis for this task is based on work done at TU Delft, since preliminary work on the field of feed-forward control accounting by a WT controller was done by their group. This task started with the beginning of the project (M1) and was initially planned to be completed by the mid-term point (M18). Due to the unforeseeable amount of work necessary to generate a linearized model, deviations from Annex 1 occurred. Further information on the delay can be found below section 5.1.

One of the main challenges tackled over the 18 first months of this project has been to build a robust baseline controller providing basis for future applications to the feed-forward capability. Due to natural stability problems arising from floating wind turbine behaviour, negative damping as well as instabilities due to control loop zeros may occur when normal onshore control approaches are used. Therefore, three new approaches have been defined in order to add a damping capability to the controller. Their properties have been assessed numerically and with analytical models. Their final state and evaluation of performances is still dependent to the validation performed in the following tasks.

Task 3.2 Numerical evaluation of performances (M11-M18, TU Delft)

This task is led by TU Delft and was initially planned to start in M11 and to be finished by M18. Unforeseen difficulties in the dependencies of Task 5.1 however lead to a delay of the work in this task and the deliverables emerging from it. Further details on the deviations from Annex 1 may be found below section 5.1.

The evaluation of the various approaches taken on the controller must be performed through numerical simulations carried out on the whole FOWT system. For now, OpenFAST has been used as sole simulation framework due to its availability as well as its linear capabilities, suitable in the specific context of assessment of the controllers. The SOFTWIND FOWT design has been setup accordingly and in coordination with WP2. A redeveloped DTU controller is employed as a standard reference, in order to cope with incompatibility between the latest OpenFAST release and the original DLL of this open-source controller. A coupling of the required software tools occurred within Task 1.5 to ensure proper integration of the feed forward control strategy in the QBlade-Ocean simulation framework, as well as for exploitation of the controllers in a non-linear numerical context in future works.

Task 3.3 Experimental wave tank testing and validation (M7 – M30, ECN)

Over the three experimental campaigns scheduled for this task, the first one has been performed between December 2021 and January 2022. For each of the experimental campaigns, ECN is the leading partner of FLOATECH.

The already completed campaign aims at reproducing the scaled scene observed by a remote wave measurement sensor from the point of view of a wind turbine, in representative conditions for a FOWT in EU Atlantic Ocean waters. A data quality check has been performed, and a post-doctoral fellow dedicated to the data processing techniques related to the real-time deterministic wave prediction has been employed for the exploitation of the collected data and the enhancement of the real-time wave prediction system. Additionally, the interface between wave data acquired through wave gauges and wave excitation forces feeding the controller is accounted for by ECN.

Several upgrades of the SOFTWIND software-in-the-loop (SIL) test bench (ECN) are being finalized for the experimental campaigns scheduled in the second half of the project, based on both 1 degree of freedom (DoF) and 6 DoF software-in-the-loop actuators. Mechanical interfaces, internal sensors and data fluxes are now specified and will be available and setup for the upcoming campaigns. The specifications from the controller designed by TU Delft in Task 3.1 have been integrated into the software and modelling chain running on SOFTWIND. The measurements expected by Seapower for exploitation and completion in WP5 have been specified together with ECN.

Task 3.4 Experimental offshore testing and validation (M1 – M30, ECN)

The experimental setup aimed at validating the remote wave sensing device developed by Next Ocean BV (NO) and installed onboard the BW Ideol 2MW FÓWT is now operating. Development and testing of the radar control software was finalized by NO before shipment of the system to SEM-rEV test site. Design, installation and commissioning of the data acquisition and radar control system were finalized by NO in close cooperation with BW Ideol in June 2022. Engineering, design, manufacturing and installation of a support structure to be fixed along the wind turbine tower and installation of a radar at 14 m height was finalized by June 2022. This require rope access works to be carried out. The preparation of offshore works, including the validation of an innovative binding technique (Cold Pad) has been performed under BW Ideol HSEQ (Health, Safety, Environment and Quality) standards and requirements. The NO device is now in operation, and its full integration to BW Ideol scada and data stream is ongoing in order to ensure proper functionality of the system and storage of recorded data.

ECN has consequently adapted its wave monitoring strategy with a second datawell wave buoy moored in a close vicinity of the FWT and is due to supply Seapower with wave reference as well as tidal data. Exploitation and validation works are now underway.

Deliverables completed:	none
Deliverables passed due date:	D3.1 – Advanced open source wind turbine controller (TU Delft) The developed and validated controller will be made available during the course of the project. This deliverable was initially planned to be submitted by M18. A request for a four month extension has been made. The reasons for the deviation from the expected schedule are listed in section 5.1. D3.2 – Controller development, findings and validation against numerical simulations M18 (TU Delft) The technical report detailing the fundamentals, development strategy, properties, behavior and performances of the controller will be provided during the course of the project. This deliverable is still pending as the content is strongly based on the planned development within D3.1. The reasons for the deviation from the expected schedule are listed in section 5.1
Milestones completed:	MS5 - Communication package (M18)
Milestones passed due date:	MS5 is passed once Deliverables 3.1 and 3.2 are completed

1.2.4. Work Package 4 - Active wake mixing in floating wind turbine farms (TU Delft)

WP4 began in month 6 of the project and has been ongoing ever since. WP4 leader is the TU Delft. Further partners involved in this work package are the TUB and Seapower. The main objective of work package four is the development of fundamental knowledge, technology, and control algorithms for active wake mixing in floating wind farms. A better understanding of the fundamental physics behind wake mixing will allow for better turbine operation such that wake mixing can be enhanced. Part of the control technology also encompasses the mechanical aspect of floater design such that controls and floater can synergize, something often called controls co-design. To that end, WP4 has four different research goals, where each goal is a subtask of WP4:

Task 4.1 – Achieve a fundamental understanding of the physics underlying the active wake mixing concept.

Task 4.2 – Develop technologies that promote wake mixing through the design of advanced floating wind turbine structures and control technologies.

Task 4.3 – Develop integrated design algorithms to simultaneously optimize the control algorithm and floater design.

Task 4.4 – Validate the technologies developed in objectives (2) and (3), which are aimed at promoting wake mixing in floating wind farms, through simulation and dedicated wind tunnel experiments.

Task 4.1 - Basic science behind active wake mixing (M7 – M16, TUB)

The task started in M7 of FLOATECH and was concluded with the submission of Deliverable 4.1 in M16. It focuses on the fundamental physics behind wake mixing. Furthermore, a preliminary investigation into the effect of platform motion, control input, and atmospheric conditions on wake mixing is also included in this task. The simulation tool developed in WP1 was used for this investigation. The main findings in this task show that using existing wake mixing strategies, such as dynamic induction control (DIC) or dynamic individual pitch control (DIPC), will cause the floating turbine to be excited in translation and rotational degrees of freedom. These motions have a positive effect on downstream wind speeds. Downstream wind speeds increase either through the fact that the wake is being deflected or because the process that increases wake mixing is enhanced. This can be enhanced by increasing the control input (i.e. the blade pitch angles). These results hold even for turbulent inflow cases, although the effect is more nuanced as turbulence causes natural mixing to occur. The work in Task 4.1 was presented at several conferences (Wind Energy Science conference and Torque2022) including a published conference paper (doi:10.1088/1742-6596/2265/4/042011) and a journal paper that will be submitted this year. Furthermore, the deliverable for this task has been submitted on time and has been accepted.

Task 4.2 - Design of novel floating wind turbines for active wake mixing (M7 – M24, TU Delft)

Task 4.2 builds on the results of Task 4.1 and is currently ongoing. It is primarily a cooperation between TU Delft for control design, and Seapower for platform design. The motion of the platform is expected, based on the results presented in Task 4.1, to be effective in further enhancing wake recovery, provided that the oscillatory response of the platform is able to increase the favorable wake recovery behavior. Thus, Task 4.2 has the purpose to find an optimal design configuration mainly with respect to the adopted control strategy requirements. Nonetheless, beside the control related constraints, other restrictions or objectives can be accounted for in the optimal configuration search process, for example considering station keeping and structural limitations or cost-related issues. This makes the development of this optimization also useful for other work packages.

An optimization framework using a simulation-based approach has been developed, which can be used for the chosen type of floater-turbine configuration. A state-of-the-art FOWT analysis code has been utilized in order to account for all the relevant physical phenomena affecting the FOWT response: aerodynamics, hydrodynamics, mooring lines, mass, and inertia characteristics. The developed framework deals mainly with the problems involved in platform modeling and has the following main objectives:

- Pre-process the geometry of the platform for use in hydrodynamic codes for characterizing the wave-body interaction behaviour of each configuration;
- Pre-process mooring lines and check for preliminary station keeping limitations (for example, a maximum surge limit has been imposed to restrain excessive surge excursion in case of too slack or long mooring lines);
- Implement an optimization procedure, using a well-established optimization algorithm.

In this phase of the work, the optimization framework is implemented in Python language and uses the following open-source codes:

- Gmsh for geometry and hydrodynamic calculation grid pre-processing;
- Capytaine for hydrodynamic calculation;
- Map++ for preliminary mooring calculations;
- Python scripts for overall calculation management;
- NREL OpenFast for FOWT simulations;
- Scypy "differential evolution" algorithm for optimization.

At the present stage of the task development, the analysis is restricted to finding a configuration able to increase the yaw oscillation response in still water at a specific frequency, while limiting the surge motion below a given limit, and minimizing the overall cost variations induced by changes in geometry and mooring system dimensions.

Task 4.2 also mentions research into a teeter hinge. A teeter hinge allows a 2-bladed turbine to both be tilted and yawed, introducing a tilt- or yaw moment or a combination of the two. To analyse the effect of a teeter hinge at an early stage, it can be mimicked by using individual pitch control (IPC). With IPC it is possible to apply tilt and yaw moments to the turbine. Using engineering models, it is possible to calculate the yaw and tilt moment from the teeter hinge, and use IPC to emulate that effect. This way a high-level study can be carried out to investigate the effectiveness of the teeter hinge.

Further research can be carried out by attempting to exploit well-known instabilities in floating wind turbines. Most notable are the pitch instability (which comes from closing a control loop) and an instability called roll-yaw lock. By bringing the floating turbine into such an instability the desired movement can be realised without the need for significant control input.

<u>Task 4.3 - Development of integrated design routines (M7 – M31, TU Delft)</u>

Where Task 4.2 focuses on independent control design and optimization, the framework developed in Task 4.2 will be combined in Task 4.3. This is achieved by using control development strategies that can be iterated quickly. An example of such a strategy is robust control. With robust control, so-called weights can be used to shape controls such that certain closed-loop performance is achieved. If the floater optimization from Task 4.2 provides desirable dynamics, a closed-loop controller can be designed using those dynamics as targets for robust control optimization. Although Task 4.3 has officially started, the focus is now on Task 4.2 as a large portion of the work in Task 4.2 will be carried over to Task 4.3. It is expected to be finished on time.

Task 4.4 - Numerical and experimental validation (M13 – M33, TU Delft)

Task 4.4 will combine the findings of Task 4.2 and Task 4.3 and test these in the wind tunnel. Task 4.4 has not yet started officially, but the first preparations have begun. Most notably is the arrival of a WindShape for a new wind tunnel at TU Delft. Furthermore, a hexapod is made available that can be used to mimic the sea state. Moreover, the TU Delft started to explore novel wake measurement techniques. This way hardware-in-the-loop simulations can be carried out. The hexapod can be used to represent the optimized floater. As back-up the wind tunnel facilities in Aerospace Engineering faculty of the TU Delft can also be used. Task 4.4 is expected to be finished on time.

Deliverables completed:	D4.1 – Study on the physics underlying the active wake mixing concept Study on the physics underlying the active wake mixing concept has been carried out.
Deliverables passed due date:	There were no delays in the submission of deliverables in this reporting period
Milestones completed:	No Milestones were due within reporting period 1
Milestones passed due date:	No Milestones were due within reporting period 1

1.2.5. Work Package 5 - LCOE and market value evaluation of proposed technologies and scale up (Seapower)

Since the objective of this WP is the evaluation of the impact the technologies developed in WP3 and WP4 have on the LCOE and market value of FOWT, this work package will be carried out at the end of FLOATECH. Thereby, no active work has been done within the reporting period 1 and will start in M22 in accordance to Annex 1 to the Grant Agreement.

1.2.6. Work Package 6 - Dissemination, Communication and Exploitation (EURO)

Work package 6 (WP6) started at the beginning of the project and will continue throughout its duration. This WP deals with the coordination of the communication, dissemination and exploitation activities and effective interfacing with the stakeholders and related communities. The objectives of this WP are to:

1. Identify the potential different routes for innovation and exploitation of the project results in order to maximize the post-project impact on a wide range of stakeholders;

2. Disseminate the information about FLOATECH to stakeholders, scientific community and to the public at large in order to engage the community behind the project, and to transfer knowledge and results;

3. Provide the maximum visibility of the project through tailored communication activities, aimed at raising awareness about the potential of FLOATECH and showing its impact and benefit to society;

4. Ensure that all data used within the project are available in accordance with H2020 Open Access Data Policy in order to boost the exploitation of the results through direct access to project data.

WP6 is led by EURO but all partners are involved in this WP dedicating time for this activity along the whole lifetime of the project.

Task 6.1 - Plan for Exploitation and Dissemination of the project results (M1 – M6, EUR)

Within this task, deliverable D6.2 was prepared and submitted as planned at M6 (June 2021). The document is composed of 2 main parts:

1. *Communication and dissemination strategy* including a description of the target audiences, messages, rules, communication tools and dissemination actions planned during the project lifetime. It also includes a section on impact assessment and KPIs.
2. *Exploitation strategy* including an overview of the preliminary list of exploitable results, the actions planned to achieve the exploitation of the project results and increase the impact of the project, as well as a section on open access and intellectual property.

The deliverable has been updated at M20 including updates about the communication and dissemination actions performed within the first year and a half, a report on KPIs and updates on the exploitation activities planned until the end of the project.

Task 6.2 - Dissemination actions (M1 – M36, EUR)

During this first reporting period we performed several dissemination actions to reach the largest possible number of people in the sector of offshore wind energy:

- As a starting point, during the first 6 months of the project, the consortium identified a list of **stakeholders** that should be targeted for the dissemination of project results among different categories of target groups:
  - academic and research community, industrials, international standardization bodies, government bodies;
  - EU and industrial networks;
  - other EU projects.

This list, that is not exhaustive since it is constantly updated, has been included in the PEDR (D6.2). We have also noticed great interest in the project from the online community on LinkedIn, where more than 400 people are following the FLOATECH page. Also, the number of persons signing up for our biannual newsletter has constantly increased, reaching almost 400 subscribers.

- In this first reporting period, we have participated in **two exhibition fairs** to specifically target industrial stakeholders:

  - We took part in the *WindEurope Electric City exhibition on November 23-25, 2021 in Copenhagen (Denmark)*, where a project booth was located at the Innovation Park, the pavilion designed to promote research and findings of European projects and start-ups. Project partners from TUB and EURO could meet several industry representatives, researchers and stakeholders in the field of offshore wind and presented the projects latest developments. The project concept, objectives and expected outcomes were also presented on the stage of the Innovation Park, where the audience expressed much interest for the QBlade-Ocean simulation tool which is expected to perform simulations of floating offshore wind turbines with unseen aerodynamic and hydrodynamic fidelity. The tool was released in open source at the end of the first reporting period. For more information: https://www.floatech-project.com/post/floatech-showcased-at-the-windeurope-electric-city-2021.

  - During the latest *WindEurope annual event that took place on April 5-7, 2022 in Bilbao (Spain)*, the FLOATECH project and the MSCA-ITN FLOAWER project collaborated to organise a side event on the theme 'Academia and Industry: synergies to boost floating wind". Attended by over 80 people, this joint event allowed academic and industrial partners of the two projects to present their findings and enhance discussions with interested people in the field. More information: https://www.floatech-project.com/post/floatech-is-organising-a-side-event-during-the-windeurope-annual-event.

- To ensure that the project partners and other external targeted users have the material and experience necessary to use QBlade-Ocean to its full capability, the team from TUB organised an online **technology workshop** on the use of QBlade-Ocean that was held over 3 days, from the 22nd to the 24th of June 2022. In addition to participants from within the FLOATECH project, early-stage researchers (ESR) from the FLOAWER MSCA-ITN project and other individuals active within industry were also invited to the training, in order to improve the uptake of the software.

- We participated in two **external events for scientific dissemination** where partners presented the work done within the project:

  - (Semi) plenary talk at the European Control Conference (ECC21) on “Closed-loop Dynamic Wind Farm Control” by Jan-Willem van Wingerden (TU Delft) – July 1, 2021 (online)

  - Conference paper presentation at the conference TORQUE 22: "Using the Helix Mixing Approach on Floating Offshore Wind Turbines" by Daniel van den Berg (TU Delft) on 1-3 June 2022, Delft (The Netherlands).

- Conference paper presentation at the conference on Ocean, Offshore and Arctic Engineering (OMAE2022): "Second-order difference- and sum-frequency wave loads in the open-source potential flow solver NEMOH" by Ruddy Kurnia (ECN) – 5-10 June 2022, Hamburg (Germany)

- A video presentation of the QBlade-Ocean simulation tool has been created and disseminated in September 2021 by the team at TUB to illustrate the functioning of the software developed within FLOATECH: https://www.youtube.com/watch?v=S6_NJ8JYKsc

- All **deliverables** submitted during this first reporting period are available for download in the dedicated page of the website (https://www.floatech-project.com/deliverables) and on the project community on Zenodo (https://zenodo.org/communities/floatech/).

Task 6.3 - Exploitation plan of the project results (M1 – M36, EUR)

The exploitation strategy outlined in the Grant Agreement has been further developed and outlined in the PEDR submitted at M6 and will be updated at M20.

The preliminary list of project outputs identified in the GA has been updated under the lead of EURO in May-June 2022: all WP leaders have been requested to identify the main **knowledge outputs (KO)** expected to be achieved within each work package and to provide information on each KO. Among the list of 9 KO identified by the WP leaders, the consortium selected **5 potential Key Exploitable Results** which will be analysed in detail during the exploitation seminar planned to be organised on 4-6 October 2022 within the **Horizon Results Booster** service (Module C).

Task 6.4 - Communication activities (M1 – M36, EUR)

Several communication materials and tools have been created in this first reporting period:

- The project **logo**, **visual identity** and **templates** (deliverable, poster, ppt) were created at the start of the project and made available to project partners to help them to communicate about the project in a uniform, consistent, and professional manner.
- At the start of the project a **one-page project description** was drafted to summarize the most important information related to the project (scope, objectives, messages) to help the consortium to communicate the right information about the project.
- A project **flyer** was prepared in May 2021. This has been distributed to partners and printed on the occasion of events where the consortium participated to promote the project and present its results.
- A project **poster and roll-up banner** have been printed and used during external conferences and events attended by the consortium to promote and present the results arising from the project.
- The first 3 issues of the newsletter have been created in July 2021, January 2022 and June 2022 and were sent out to the project mailing list and disseminated through social media and the contact networks of the project partners, to maximize its dissemination. These are also available for download at https://www.floatech-project.com/newsletter.
- The FLOATECH project website was launched and published online in April 2021 and is being constantly updated with news, events announcements and new documents.

More information on the content and structure of the website can be found on deliverable D6.2.

- A LinkedIn page and a Twitter account have been created in the first months of the project to develop a community of people interested in the project, to raise awareness on the project launch and objectives and to allow for more interaction with similar projects and initiatives.
- A press release including the most important information related to the project (scope, objectives, messages) was drafted in June 2021 to officially communicate the launch of the project. It is available at floatech-project.com. This was published by project partners on their institutional websites and translated also in other languages (in French by ECN here: https://sem-rev.ec-nantes.fr/sem-rev/actualites/lancement-projet-floatech). An additional press release was published by TUB in August 2021: https://www.tu.berlin/en/about/profile/press-releases-news/2021/august/harvesting-wind-on-the-high-seas/.
- **11 articles in the national and regional press** were published on the initiative of some project partners (TUB, TU Delft, Unifi)
- The project coordinator presented FLOATECH during a **radio interview** on Radioeins (German radio station) on the independence of European energy on 21 May 2022
- The consortium participated in some external **events** to raise awareness of the project:
    - Project presentation at the conference ASME Turbo Expo 2021, during the tutorial session "Recent developments in wind turbine technology and research" by Alessandro Bianchini (Unifi) – 7-11 June 2021, (online)
    - Project presentation at the TWIND Summer School focusing on floating wind in collaboration with the TWIND project, by TU Delft - 5-9 July 2021 (online)
    - Project presentation within the lecture "Challenges in developing the new generation of wind turbine", FOWE Summer School in collaboration with the STEP4Wind project, by Unifi – 4-8 October 2021, Como (Italy)
    - Project presentation at the OWEMES Conference - the Italian perspective by Seapower and Unifi – 2 December 2021, Roma (Italy)
    - Project presentation at the conference ASME Turbo Expo 2022, during the tutorial session "Challenges in developing the new generation of wind turbines" by Alessandro Bianchini (Unifi) – 16 June 2022, Rotterdam (The Netherlands)

The complete list of communication activities and related KPIs is available upon request to EURO, the WP6 leader.

Task 6.5 - Data management

A first version of the FLOATECH **Data Management Plan** was prepared and submitted as a deliverable (D6.1) at M6. The aim of the DMP is to define how data is handled and stored during and after the project and to list all data collected, processed and/or generated by the project. This deliverable was updated at M18 (June 2022) and another update is planned at the end of the project (M36).

Work package leaders have been involved from the very beginning to define how to implement the 'FAIR' approach defined by the EC ("findable, accessible, interoperable and re-usable"). All partners have been sensibilized on the necessity to make data as open as possible and to publish all publications in open access.

All project publications and datasets have been uploaded on **Zenodo**, where a FLOATECH community was created in April 2021: https://zenodo.org/communities/floatech/

Deliverables completed:	D6.1 – Data Management Plan (M6) The DMP describes the data management life cycle for the data to be collected, processed and/or generated by the project. An updated version of this document was submitted at M18. D6.2 – Plan for exploitation and dissemination of the project results (M6) The PEDR summarizes the beneficiaries' strategy and concrete actions related to the protection, dissemination, communication and exploitation of the project results.
Deliverables passed due date:	There were no delays in the submission of deliverables in this reporting period
Milestones completed:	MS9 - Communication package (M6)
Milestones passed due date:	MS10 - PEDR successful implementation (M18). Being the means of verification the mid-term review and KPI Reports, this milestone will be achieved at M20, when a new version of the PEDR will be submitted to the EC.

1.2.7. Work Package 7 – Management of the Project (TUB)

All work that is carried out in this work package intents to secure the overarching interest of the European Commission and the FLOATECH consortium by guaranteeing a successful project completion on time and within the limits of the financial resources. To do so, a governance structure is put into place that divides the project into seven work packages, see Figure 2. Within each work package, every beneficiary implements the work schedule independently and contacts other work packages whose work is interlinked according to their task definitions and work plans. The innovation advisory board (IAB) consist of market leading companies in their respective fields that assist in the scientific strategy and the exploitation of results created during the project. The IAB is constituted by the following companies and associations:

- WEAMEC
- WAB e.V.
- DNV GL
- UL international GmbH
- Wind Europe
- Eolfi
- TÜV Nord

The work package is structured in three tasks:

1. Task 7.1 – Project Management (M1 – M36)

2. Task 7.2 – Governing Bodies Meetings (M1 – M36)

3. Task 7.3 – Project Reporting and Interaction with the EC (M1 – M36)

The tasks above are led by the work package leader TUB and require the participation from the entire consortium. A total number of three deliverables is part of this work package and for each, the work package leader TUB is named the main beneficiary.

Figure 2 - FLOATECH Governance Structure

<u>Task 7.1 – Project Management (M1 – M36, TUB)</u>

To ensure a high level of quality of the numerous deliverables, technical reports and other publications that will emerge from different members of the FLOATECH consortium, a quality management plan (QMP) was put in place in the beginning of the project. Thereby, a quality standard that can be fulfilled by all partners is defined and procedures that ensure the accomplishment of the quality is defined. Furthermore, the plan serves as a handbook to the organizational structure within FLOATECH that defines governance structure, the decision-making process and the global deadlines of milestones and deliverables that have to be met by the consortium.

The day-to-day management of the project takes up the largest time share, thereby administrative assistance to the consortium is given whenever required. Financial questions are handled by the financial officer Dominik Krieger (TUB) which this far focused on the reporting duties towards the EC. The consortium agreement (CA) was amended to follow an appeal by Saipem for an additional anti-corruption clause. Deliverables were, if uploaded according to the processed detailed in the QMP by the main beneficiary, always submitted by the

Coordinator. Finally, whenever questions that should be discussed with the project officer were raised in a meeting by a FLOATECH member, either a clarifying online-meeting was organized or mail was sent to the corresponding EC project officer at the time.

To guarantee a secure, fast and accessible exchange of data, the PMT initiated a shared tubCloud folder and registered every regular user from FLOATECH as members to allow them to access the shared folder via an ownCloud-client. The ones that didn't apply for the registration have access to the same folder via a weblink and a password that is shared to the consortium. The tubCloud folder was set-up and working by the beginning of M3 (March). Apart a temporal downtime due to technical difficulties by the host TUB, the tubCloud prooved itself as a viable option that is frequently used to share simulation results, dissemination documents, presentation slides etc.

Structured tables were the assembly of the Steering-Committee (SC), Executive Board (EB) can be looked up are provided on the tubCloud. Additionally, a contact list containing name, affiliation and mail address of every person working in FLOATECH was created by the PMT and is kept up to date. To promote fast and direct communication within the consortium every beneficiary is asked to communicate matters directly with the person of interest and raise questions or problems in one of the regular or an extraordinary meeting.

After the initialization of a workshop to raise awareness of the predominantly male workforce that participate in R&D in the energy field and the role this unequal gender distribution might play on research perspectives, the EC project officer at that time suggested to not continue with the planning. The reasoning behind this decision was that gender specific perspectives play a minor role in the field of FOWT and that the teams were already formed complying to the ethics and gender requirements of each participant (mostly universities).

Task 7.2 – Governing Bodies Meetings (M1 – M36, TUB)

The FLOATECH consortium regularly meets in two groups, one being the executive board that consists of the work package leaders. In those meetings the progress is presented and difficulties and deviations from the work plan are discussed. The other being open to the entire consortium (including IAB) with the steering committee (SC)[2] being a mandatory participant. It was the responsibility of the PMT to organize the meetings (or to assist in case of an in-person meeting at the campus of a project partner), to set and distribute the agenda and to compile the minutes of meeting. In the first reporting period, the EB came together three times and reported the progress within each of the work packages. Due to COVID-19 restrictions, the EB-meetings had to take place online. This format worked well and little to no influence on the ability to present the work progress was noted. The EB-meetings took place on:

- March 13th 2021
- October 10th 2021
- March 18th 2022

[2] The SC comprises a representative of each beneficiary and is the decision-making body of FLOATECH.

Four meetings on consortium level (progress meetings) took place. Similarly to the EB-meetings, pandemic related travel restrictions forced us to have most of those initially planned in-person events online. The most recent meeting however took place as a hybrid event in Delft just before the wind energy conference Torque22. Most of the consortium was able to travel in person and to finally meet in person. For the ones that couldn't, a *Teams*-link was provided. Following each of the progress meetings, a discussion block was planned to discuss any decision on a consortium level with the SC and to decide on future events to target, mitigation actions, etc. The progress meetings took place on:

- 19. & 20.01.2021 – Kick-Off Meeting
- 22. & 23.06.2021
- 02. & 03.12.2021
- 30. & 31.05.2022 – (first in-person meeting in Delft at the TU Delft campus)

Task 7.3 – Project reporting and interaction with the EC (M1 – M36, TUB)

The communication with the corresponding EC project officer was initiated whenever questions arose in the PMT or the consortium. The first reporting requirements will be fulfilled by the submission of the present document. As the reporting of such a large consortium requires organization, the PMT initiated a meeting together with the outgoing and incoming project officers Loïc Blanchard and Baris Adiloglu on June 29th in which the general process of the mid-term review (report and meeting) was discussed. On July 4th a project meeting was organized to communicate the information obtained from the EC project officers to the consortium and the reporting requirements of each beneficiary together with internal deadlines were defined. The submission date of this mid-term was set to September 8th in coordination with Baris Adiloglu and the mid-term review meeting was set to September 21st.

Deliverables completed:	D7.1 – Quality Management Plan (M3) The QMP defines the quality that deliverables, publications, technicals reports, etc. that emerge from FLOATECH should meet. A quality control procedure is detailed that aims to assure that the quality of a document is in line with the expected level of quality. Furthermore, the governance structure and the decision making process is defined. By providing the abovementioned information, the document serves as a reference document for all beneficiaries in the case of uncertainties. Depending on decesions that are made on a consortium level, the QMP may be adapted and thus is a live document that is continuously updated.
Deliverables passed due date:	There were no delays in the submission of deliverables in this reporting period
Milestones	No Milestones were planned within WP 7

1.3. Impact

The expected impact of FLOATECH that was detailed in Section 2.1 of the DoA in the Grant Agreement and still remains relevant. The two overarching impacts are to:

1. Lower the Levelized Cost of Energy
2. Increase the market value of wind power.

Several achievements (A) that should be accomplished throughout the duration of FLOATECH were determined that are aimed at enabling to reach the expected impacts listed above. Those achievements are tightly coupled to the objectives of the several work packages described in section 1.3. During reporting period 1 each of the achievements of the first Impact (Lower the LCOE) has either been accomplished or significant progress has been made:

- A.1 – Development of the design and simulation environment QBlade-Ocean

The tool QBlade-Ocean has been finalized and was released at the conclusion of this reporting period. While thorough validation has already been carried out, the consortium continues in the identification of uncertainty reduction that ultimately will allow a decrease of safety factors and thus a reduction of CAPEX (see Section 1.3 below WP1 and WP2 for more information).

- A.2 – Development of active feed-forward wave based control

The first planned experimental campaigns to collect wave data have been carried out and the full-scale prototype of a radar has been mounted on the test site. Both steps are crucial to fully develop and test the control strategy. The controller interface has been successfully integrated into QBlade-Ocean and the controller itself is currently under development. Active wave based control allows for material saving and thus CAPEX reduction as fatigue loads are reduced due to damped out oscillations of the FOWT (see Section 1.3 below WP3 and WP1 for more information).

- A.3 – Development of active wake-mixing control

Two wake mixing strategies are thoroughly investigated in WP4. Thereby, both control strategies can be applied to simulations in QBlade-Ocean and their effect on following turbines be investigated. The knowledge gained throughout the analysis of both strategies will lead to new floater designs that promote the positive effects of wake mixing and an optimization framework that allows for a simultaneous optimization of control algorithm and floater design. The positive influence on LCOE is accomplished by an increased efficiency of downwind turbines due to higher wind speeds encouraged by an accelerated wake breakdown (see Section 1.3 below WP4 for more information).

The second Impact (increase the market value of wind power) is similarly achieved by the development within the respective WP.

- A.1 – Development of the design and simulation environment QBlade-Ocean

QBlade-Ocean allows for an intuitive and thus accelerated design process of site specific FOWT, enabling a faster exploitation of highly energetic sites in deep waters.

- A.2 – Development of active feed-forward wave based control

The reduction of wave-induced oscillations throughout the lifetime of a FOWT enhances power production in different sea states and increases the capacity factor. Reduced fatigue loads also allow the design of even larger rotors, leading to an increase of the market value of wind power.

2. Update of the plan for exploitation and dissemination of result (if applicable)

The PEDR has been updated. The new version is submitted in parallel to this report in the Continuous Reporting system and will be updated on the webpage below (D6.2).

3. Update of the data management plan (if applicable)

The data management plan has been updated. The new version was submitted in the Continuous Reporting system on June 30th 2022 (D6.1).

4. Follow-up of recommendations and comments from previous review(s) (if applicable)

Not applicable.

5. Deviations from Annex 1 and Annex 2 (if applicable)

5.1 Tasks

Work Package 1

Task 1.3 – During the execution of T1.3 (Task leader ECN) it was found that significant deficiencies existed with the existing solver NEMOH. These technical deficiencies impacted both accuracy of the solution method and the execution time of the calculations. It was necessary to correct these in order to ensure that the first-order input for the calculation of the QTFs was valid and free of errors for arbitrary platform geometries. These corrections were crucial prior to conducting validation tests of the implemented QTF functionality. Despite this, validation cases for the QTF calculation has been conducted as far as was possible without correcting the aforementioned deficiencies. The baseline implementation of NEMOH is currently being adapted to correct these issues and ensure a robust solver for public release. This shall be completed by the end of M22.

Work Package 2

The definition of long-term environmental conditions for an offshore site in the European Union (in preparation of Task 2.2 – Quantification of uncertainty reduction gained through QBlade-Ocean) was not initially planned. With most of the team's experience being in the simulation, modelling and certification of onshore wind turbines, it was assumed that a similar approach, based on the definition of a set of standard wind turbine classes, would be adopted. After examining the relevant technical literature and international standards, it became apparent that for offshore wind turbines the inflow conditions to use in the simulation of the various Design Load Cases (DLCs) required by international standards depend on specific installation sites. After re-examining the technical literature for ready-to-use inflow conditions suitable for Work Package 2 without success, appropriate inflow conditions were computed. This deviation required more work than expected from all beneficiaries involved in WP2. However, we envision that it will result in an additional publication on the topic in the future.

The simulation of the SOFTWIND 10MW wind turbine model in irregular wind and waves in OpenFAST has shown to be problematic. The problem has manifested itself for the OpenFAST simulations only and not for the other codes involved in the study. At the time of writing, only a partial comparison to OpenFAST results in these conditions is possible. A full comparison in all the other conditions mentioned in section 1.2.2.1 was performed. Moreover, this constitutes an issue for Task 2.2, where this model is to be used. The issue is being investigated together with possible solutions and mitigation strategies.

Work Package 3

Task 3.1 – The linearization of a model around an operating point that is needed for controller development was initially intended to be done within QBlade-Ocean. This functionality is only possible in QBlade-Ocean with significant structural modifications to the code. Thus, the decision was eventually taken to build an equivalent model in the open-source software OpenFAST that possesses this capability. Although this deviates from the desired functionality, the resources necessary for the implementation work which would have been required was insufficient within the scope of the allocated time and funds. Additionally, this decision came relatively late in the progress of WP1, due to miscommunication between partners, and led to delays in the timeline of the deliverables. The setup and especially the validation and debugging of the newly build OpenFAST model is a time-consuming process that wasn't planned in the initial proposal and led to a delay of the development of the controller.

Task 3.2 – The delay in the development of the controller (described below Task 3.1) and the lack of access to a complete and validated QBlade-Ocean code (described below Task 1.5) lead to a delay within Task 3.2 as the proper validation of the controller could not be started until the end of May 2022.

Task 1.5 provides the development of a framework to couple a TU Delft -style controller to QBlade. Even though this was performed successfully and on time, the result of this task could not be used within validation of the controller as initially planned throughout Task 3.1 since access to a QBlade-Ocean version capable of simulating free-floating wind turbines was not yet available. This is mainly a result of erroneous planning before FLOATECH started since a validated and fully capable QBlade-Ocean code was not planned to be provided until mid-May 2022, 1.5 months ahead of its official release.

Milestone MS5 was delayed as a knock-on effect of the aforementioned delays.

Should D3.1 be delivered in the 4 months requested by the consortium, work could be pursued with limited implications in the context of the tank experiments scheduled in T3.3 for the validation of this controller.

Work Package 6

A knowledge portfolio was planned to be prepared during the first year (with a part gathering knowledge already available before the project) and to be updated via a questionnaire on a yearly basis. This was not done because each partner identified and agreed on the background needed to implement the action or exploit the results of the project in the Consortium Agreement.

If needed, we will further work on this part with the help of the expert from the Horizon Results Booster during the second reporting period.

5.2 Use of resources

Next Ocean BV (Work Package 3)

Two deviations from resources that were planned to be allocated in accordance with Annex 1 were unavoidable throughout reporting period 1. Both points are mentioned below, followed by their consequences on the planned budget as well as mitigation plans to not surpass the planned budget for the entire project.

1. The installation work of the radar that conveys the wave data to the active wave-based controller on the SEM REV offshore test site was initially planned to be outsourced to a subcontracted third party. Due to safety requirements (Offshore Safety Training required for access to BW Ideol turbine) and limited availability of third parties, it was decided to take on this work ourselves instead of outsourcing it.

2. The hours needed for preparation, testing, installation and commissioning of the radar system in the field were underestimated.

As a result of bullet points 1. and 2., significantly more person month than foreseen until commissioning the system were necessary to comply with the set time frame defined in the DoA. Thus, 85% of the planned hours have been budgeted up until now although the time-consuming task of data processing has just begun. Therefore, it will be unavoidable to exceed the budgeted hours. At the same time, as mentioned in bullet point 1, it is expected to spendmuch less on outsourcing work to third parties. Depending on whether it is needed to outsource anything concerning decommissioning of the radar system at the end of the project, it might not be necessary to spend the allocated budget for this, which would allow for the compensation of additional staff budget mentioned under bullet point 2.

5.2.1 Unforeseen subcontracting (if applicable)

Not applicable.

5.2.2 Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable.

HISTORY OF CHANGES		
VERSION	PUBLICATION DATE	CHANGE
0.1	24.08.2022	Initial draft, Robert Behrens de Luna (TUB), support by WP leaders
0.2	29.08.2022	Reviewed by EURO
0.3	05.09.2022	Reviewed by Joseph Saverin (TUB)