SENSE Hub MOOI622002 Public Report Feb 2023 until Jan 2024 (M1-M12)

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Introduction – 21 March 2024

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The project is carried out with Top Sector Energy grant from the Ministry of Economic Affairs and Climate, implemented by Rijksdienst voor Ondernemend Nederland. The specific grant for this project is MOOI grand round 2020.

Contents

1 Objectives of the project and cooperating parties

1.1 Problem statement and analyses

The addition of offshore solar to the offshore energy system has an enormous potential and can contribute to more than 50% of the Dutch energy consumption. The energy transition, accelerated by the energy crisis and the need to become independent from potentially hostile foreign sources of oil and gas, are resulting in enormous scaling plans for offshore wind and the required energy infrastructure. In particular, the Netherlands, Belgium, Denmark, and Germany have signed the Esbjerg Declaration (Figure 1). To ensure that optimal energy system developments are implemented, it is paramount to explore and fully unlock the huge potential of offshore solar.

Problem analyses
SENSE Hub consortium proposes to address critical aspects to enhance North Sea Energy hubs (offshore wind farms with hydrogen conversion/storage) with offshore solar.

Four domains are considered:

Offshore solar technology and effects on the environment:

- The current costs of offshore solar are still estimated to be 2 to 5 times higher than solar on land. The technology requires further optimization to become competitive.
- The energy generation performance of offshore solar over its lifetime is not yet as reliable as solar energy on land. The first grid connected projects will need to be used to shed new insights on lifetimes and possibilities to enhance the performance.
- Sustainable, 100% recycled materials should be used in next generation floaters together with an optimized strategy for end-of-life treatment of components to lower life cycle environmental impacts.
- The environmental impacts of large scale offshore solar are largely unknown. Despite positive hypotheses and first field observations, the impacts need to be monitored on the MW-pilot scale and then extrapolated through modelling studies to develop sufficient insight to responsibly implement offshore solar, co-located with wind.

Optimized integration of offshore energy system modules (wind, solar, hydrogen, storage, battery, cable, pipes):

- The energy system design concepts used in the past decades are not fully applicable anymore. New system integration services are needed to properly benefit from the vast amount of weather dependent electricity from wind and solar. Options such as cable pooling (same cable connections), energy storage and energy conversion need to be further explored from a technical and an economic perspective.
- Current assessments focus largely on the energy system on land, whereas the offshore renewable energy sector is now increasing. Secondly these assessments are not yet considering the addition of offshore solar and its potential benefits.
- The most feasible method of assessing integration of the modules and the development of sensitivity analysis and economic comparative studies is to work with

simulation models. Given the intermittency of the power generation, dynamic effects of the different energy components need to be included. To properly validate these models, data is required from actual testing through pilots.

Addressing non-technical barriers to scaling system integration concepts on GW-scale:

- Implementation of the concept needs to be tested through several legal assessments to point out current barriers and to suggest how these barriers can be removed in terms of legislation.
- Economic scenarios to understand how the technologies can interplay and create added economic value need to be based on dynamic models validated with real life data of offshore pilots and laboratory testing. Scaling up assessments, that can be used for policy referrals, will show how the future SENSE Hubs can contribute to cost reduction of electricity generation and transport onshore, and of (offshore wind generated) hydrogen production.

Public, social, political, legal, and environmental acceptance of SENSE Hub:

- The project aims to enhance the currently limited information and outreach to the public concerning the merits/disadvantages of adding offshore solar to North Sea Energy Hub plans. Of particular importance for the project is that the outcomes are useful to policymakers in order to modify/create new policies, regulations and legislation needed to realize and accelerate the clean tech solutions piloted in SENSE Hub.
- The high and rapidly increasing demand for maritime space for various functions, such as marine renewable energy infrastructure, continued gas exploration/exploitation, shipping and fishing activities, ecosystem and biodiversity conservation, recreation, aquaculture and underwater cultural heritage, as well as the multiple pressures on coastal resources, require an integrated planning and management approach. Understanding the complex landscape of stakeholders as well as the (cumulative) ecosystem effects of integrated energy parks is mandatory for a responsible and sustainable marine spatial planning of the North Sea.

1.2 Project definition and goals

The core of the SENSE Hub project is to develop an understanding of the merits/challenges for enhancing North Sea energy systems with a second, complementary intermittent energy generation source. Thereby the project addresses the integration of various energy system modules in the North Sea and the validation of the concept by focusing on the technical, economic and ecological implications of the SENSE Hub Concept.

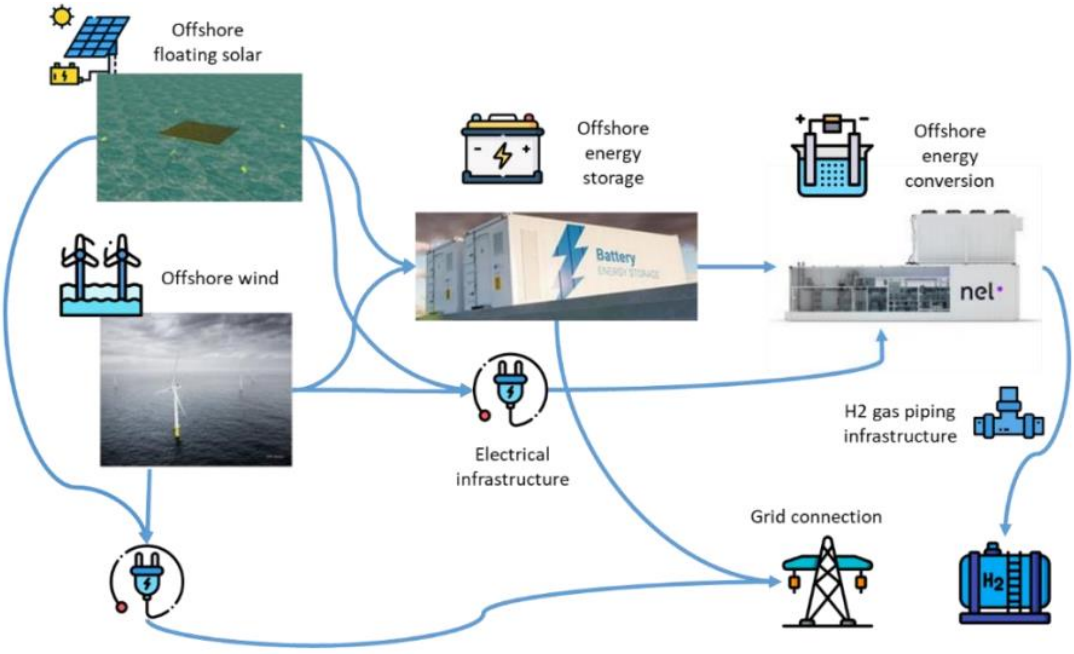


Figure 1 Illustration of the SENSE Hub Concept. A goal of the project is to identify the optimal system integration of the different energy components (connections, sizing, operational strategies)

SENSE Hub project has a duration of 4 years and is composed of 4 overarching objectives, further split in multiple SMART objectives which overlap with the project results (see Figure 2).

Overarching Objective A:

- Result 1, accelerate offshore solar acceptability, which is split further between the design, implementation and operation of an optimized offshore solar system
- Result 2, the understanding of the ecosystems effects of solar floating platforms
- Result 3, the understanding of the cumulative effects of offshore solar within wind farms

As shown in figure 2, the offshore solar farm with the improved and newly installed floating platforms, will be a unique R&D opportunity for gathering new field data to improve the ecological models, and for providing key information to the techno-economic objectives B and C. The extensive modelling effort will allow unprecedented quantification of (cumulative) effects at different length-scales, providing a solid base for the scaling-up assessment from an environmental point of view.

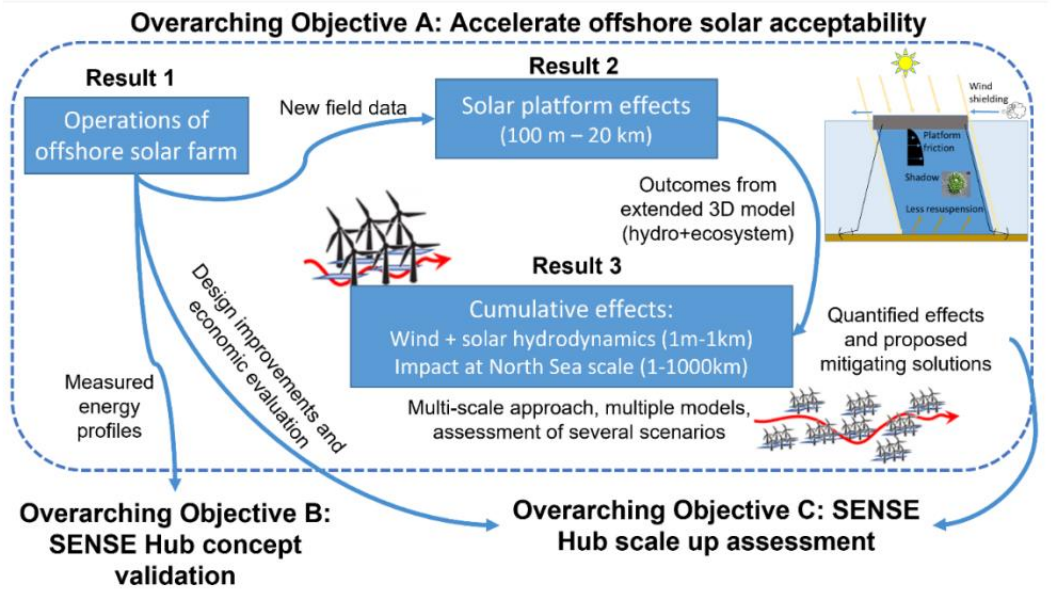
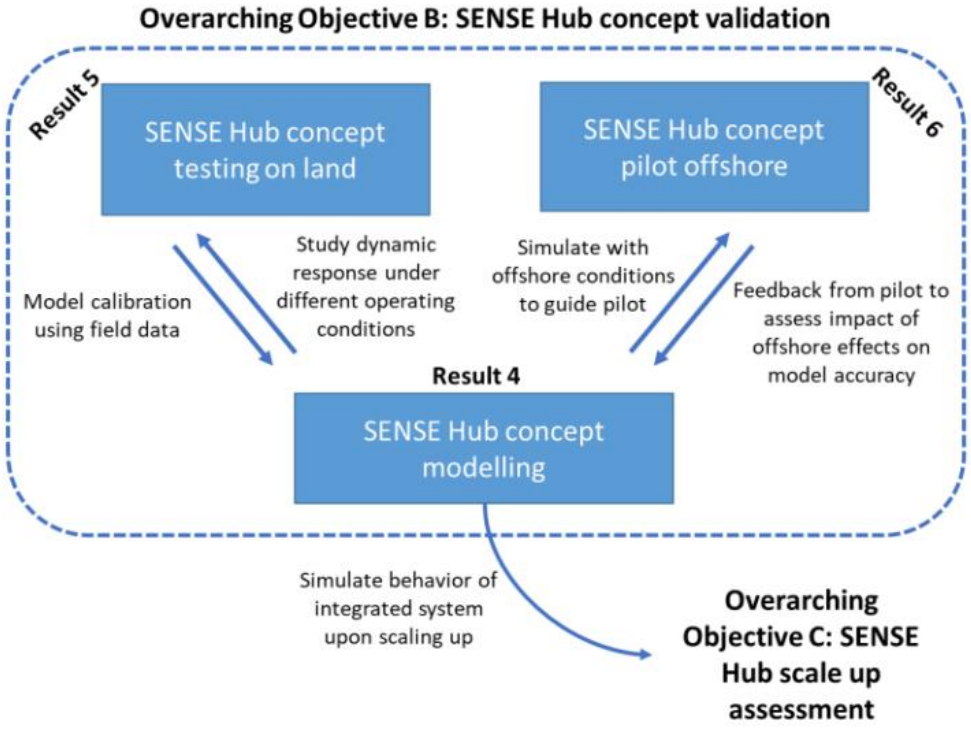


Figure 2 Schematic overview of the activities planned to reach Overarching Objective A

Overarching Objective B:

- Result 4, SENSE Hub Concept validation, which will address the dynamic model of the SENSE Hub concept
- Result 5, Extensive land tests on Switch fieldlab
- Result 6, Concept simulation at MW scale.

The interconnection between the 3 results achieved in Objective B is illustrated below:



Overarching Objective C:

- **Result 7,** SENSE Hub GW Level assessment, addressing the legal framework (Result 7) and
- Result 8, The techno-economic assessment of the SENSE Hub implementation at GW scale

Overarching Objective D:

- addresses the project governance, from technical project management, project coordination, advisory board development and engagement and implementation of the dissemination and communication activities.

1.3 Partners involved:

Oceans of Energy, start-up company developing and producing offshore solar energy systems. In SENSE Hub OOE intends to showcase, through the extended solar farm, design improvements resulting in higher power performance, lower costs and less system degradation. OOE also facilitates and contributes to the environmental field research and monitoring around the pilot farm and is responsible for achieving Result 1 of the project.

NWO-NIOZ, Royal Netherlands Institute for Sea Research is the national oceanographic institute and principally performs and promotes academically excellent multidisciplinary fundamental and frontier applied marine research addressing important scientific and societal questions pertinent to the functioning of oceans and seas. NIOZ serves as national marine research facilitator (NMF) for The Netherlands scientific community.
In SENSE Hub NIOZ will collect and analyze observations of offshore oceanographic and environmental processes, as well as numerical modelling. NIOZ is responsible to achieve Result 2 of the project.

Deltares is an independent institute for applied research in the field of water and subsurface. In SENSE Hub, Deltares will assess the cumulative effects of offshore solar within wind farms. This is crucial for responsibly scaling up offshore solar energy.

Primo Marine is an independent specialist with an extensive track record in subsea cable installation, protection and maintenance from landfalls to subsea marine infrastructures. The experience includes involvement in the planning, design, procurement, installation & commissioning of large cable installation projects as well Offshore Wind Farms (OWF's) and Export Grid Systems.
In SENSE Hub Primo Marine will provide input on Result 4, 5, 7 and 8 based on their involvement and experience in the 2GW research project for the Netherlands (TenneT) and Germany (a.o. research options to execute bundled installation and investigate the state-of the art technical possibilities)

New Ground Law is a top law firm with a strong focus on renewable energy and project development. Our experts have extensive knowledge of the regulated energy market, contracting within the energy market and the legal management of renewable energy projects, both onshore and offshore.
In SENSE Hub New Ground Law will provide insight into the relevant legal issues and help find solutions to them. New Ground Law is covering the complete work described in result 7 of SENSE Hub.

Advanced Electromagnetics BV (hereafter AE) is one of the world market leaders in the field of permanent drives and has a lot of know-how in the field of smart drives. It employs people with a development background as well as those involved in manufacturing and modelling and quality (such as one of the most challenging medical ISO 13485). The company has a lot of know-how in the field of smart drives and energy infrastructure.
In SENSE Hub AE will contribute to result 8, focusing on the conceptual design of the electrical infrastructure for the SENSE Hub Concept. AE will address the offshore considerations in the design, will evaluate the costs and will estimate the system footprint at a GW scale.

TNO is the largest fully independent Research, Development and Consultancy organization in the Netherlands. TNO provides contract research and specialist consultancy, as well as grant licenses for patents and specialist software. TNO also tests and certifies products and services, and issues an independent evaluation of quality.
In SENSE Hub, TNO will coordinate the project and will lead the work of Results 4, 5, 6 and 8. TNO will use the extensive knowledge and modelling tools to understand and optimize the SENSE hub concept. Next to this, TNO will use their Switch field lab facilities for extended land testing and validation of its SENSE Hub adapted models.

2 Activities and results over reporting period

In the SENSE Hub project the Results contain different activities with specific deliverables and milestones. Below you find an overview of the progress made in the first year of the SENSE Hub project. Some of the tasks have not been started as they are not due or are dependent of the results from an earlier tasks .

Result 1. The offshore solar system of Oceans of Energy has been extended with 160 kW optimized platforms by 2025

Activity	*Activity 1.1. Design of improved offshore solar system (Duration: M9 – M15)*	
Start-/end date	*October 2023 to May 2024*	Status: *Ongoing*
Activity 1.1 has started in November and is now running for almost three months. During this period collected data at the Offshore Test Site from the NS2OSP pilot has been utilized for design improvements. Design improvements are realized on different levels, e.g. material, component, system levels. Every design improvement is installed at sea. Because the offshore solar system is continuously operating at sea, performance data is continuously monitored which feeds in for example fatigue analysis. OOE's unique modular design enables replacement of single components and therefore an ability to test and learn from a variety of design versions at the same time. Insights from performance at sea feed into our iterative design improvement process. The learnings from NS2 resulted in improvements in amongst others floaters, connectors between the floaters, and PV mounting system. In terms of power performance NS2 has an off-grid set up since winter 2022, which enables comparisons between offshore and on land power performance. Data analysis is still ongoing but preliminary results validate modelling studies and show that offshore solar has an increased power performance compared to solar on land, due to cooling effects of the sea and more irradiance. Measurement of forces on the floaters during operations at sea have enabled two goals: (1) validation of our own numerical hydrodynamic models, and (2) a better understanding of the forces on the system which is used to improve lifetime performance. The activity outcome (design documentation and preliminary safety assessments) is considered on track to feed Activity 1.2. In the coming 5 months, OOE will use the results to improve system design of the array, apply improvements to the PV-mountings for better performance, and will further explore possibilities and concepts to capture the benefits of the inner-array protection that can result in significant cost reductions.		

Activity	*Activity 1.2. Engineering, Procurement, Construction, and Installation of NS2 extension (Duration: M15 - M27)*	
Start-/end date	*May 2024 to April 2025*	Status: *Not started*
This activity has not yet started.		

Activity	Activity 1.3. Operations and evaluation of the system (Duration:M27 – M48)	
Start-/end date	*April 2025 to January 2026*	Status: *Not started*
This activity has not yet started.		

Result 2. The local 3D hydrodynamics-ecosystem model has been developed and validated with field data, and projections of ecosystem effects of km-scale floating platforms have been made

Activity	*Activity 2.1. Field observations (Duration: M1-M24)*	
Start-/end date	*February 2023 to January 2025*	Status: *Ongoing*
Time series observations using sensors of turbidity (suspended sediments) and fluorescence (phytoplankton) have been taken between February and December 2023. Three sets of water samples for sensor calibration have been taken and analysed. Also, shorter time series of Acoustic Doppler Current Profiler (ADCP, flow velocities) data were acquired.		

Activity	*Activity 2.2. Model validation and simulations (Duration: M1-M39)*	
Start-/end date	February 2023 to April 2026	Status: *Ongoing*
The postdoc started work in November 2023. She is currently training on the 1D version of the coupled hydrodynamics-ecosystem model, implementing the 1D model for the Scheveningen location, and incorporating the implementation of floating platforms developed by Karpouzoglou et al. (2020) into the most recent model version. This includes shadow effects, platform friction, and shielding from wind forcing.		

Result 3. Cumulative effects of offshore solar within wind farms using a multi-scale modelling approach has been estimated

Activity	*Activity 3.1. Small-scale modelling of wind turbines and floating solar to correctly parameterize combined effect on hydrodynamics (Duration: M1-M12)*	
Start-/end date	*February 2023 to January 2024*	Status: Ongoing
We conducted a CFD (Computational Fluid Dynamics) analysis to study the hydrodynamic effect of placing solar panel arrays in between wind turbines. The hydrodynamic wake can result in mixing which could affect e.g. the production of algae. Therefore, it should be properly represented (i.e. parameterized) in models. We modelled hydrodynamics around such an array using numerical large eddy simulations (LES). An in-depth analysis of the extent and spreading of the wake, the orientation of the array relative to the current, and the acting forces is provided. Our analysis shows, among other things, a wake spreading increase of up to 40% relative to the array width. The results can be considered for the first design stage of a floating solar installation. We are currently finalizing the report describing this part of our work. This will serve as a basis for Activity 3.2 and subsequently Activities 3.3 till 3.5.		

Activity	*Activity 3.2. Implement parameterization in Delft3D-Flexible Mesh and test (Duration:M12-M18)*	
Start-/end date	*January 2024 to July 2024*	Status: *Ongoing*
Planning implementation with Product Owners of Deltares' hydrodynamic modelling software D-Hydro. Relevant developments identified, now deciding on how to connect with these developments.		

Activity	*Activity 3.3. Large-scale hydrodynamic model using DCSM-FM including offshore solar (Duration:M18-M24)*	
Start-/end date	*July 2024 to January 2025*	Status: *Not started*
Ongoing discussions with other projects (e.g. offshore wind) on modelling effort. Combine simulations and postprocessing for effective modelling. Foreseen start: Q3 2024.		

Activity	*Activity 3.4. Large-scale water quality modelling on North Sea scale (Duration:M24-M36;*	
Start-/end date	*January 2025 to January 2026*	Status: Not started
Ongoing discussions with other projects (e.g. offshore wind) on modelling effort. Combine simulations and postprocessing for effective modelling. Foreseen start: Q1 2025.		

Activity	*Activity 3.5. Validation of models developed in Activities 3 and 4 (Duration:M18-36)*	
Start-/end date	*July 2024 to January 2026*	Status: Not started
Validation of the models will only take place after Activity 3.3 and 3.5 have started.		

Result 4. The dynamic model of the SENSE Hub concept has been developed, validated and runs simulations for accelerated testing

Activity	*Activity 4.1. SENSE Hub concept design and scenario definition (Duration: M1-M12)*	
Start-/end date	*February 2023 to January 2024*	Status: *Ongoing*

Several meetings were held to identify relevant scenarios for the SENSE Hub concept. These included internal discussion at TNO across different departments and regular progress updates with all the consortium partners. The feedback gathered in these occasions was implemented to refine the list of scenarios under considerations. A dedicated workshop was also organized with the relevant partners of result 4 to discuss in detail the modelling requirements of the energy components in general and the electrical infrastructure elements in particular.

A list of increasingly more complex scenarios was defined, and the various aspects related to an asset simulation were discussed. These include (i) energy components to be modelled, (ii) asset configuration (how the components are connected), (iii) asset operations (how the power should be distributed across the different components), (iv) geographical locations of the assets, (v) relevant boundary conditions and techno-economic (e.g. CAPEX/OPEX) information necessary for the asset simulations, (vi) key performance indicators (KPIs) to monitor (simulations output).
In particular, two specific locations in the North Sea were selected based on ongoing/planned offshore wind farm developments, with different wind park size (medium/large), different distance from shore (closer/farther), and different power cable connection (AC/DC). The added value of offshore solar (i.e., the SENSE Hub concept) will be tested for these two representative cases.
The key energy components that will be included in (some of) the scenarios considered are: offshore wind farm and solar park (energy generation), PEM water electrolyser (energy conversion), hydrogen pipeline infrastructure and electrical infrastructure elements (energy transport), and storage options for hydrogen (line packing in pipeline) and electricity (LFP battery). Several asset configurations will be considered representing energy hubs focused on achieving (1) offshore power generation; (2) hydrogen production offshore; (3) hydrogen production onshore; (4) offshore power for hydrogen production and storage; (5) offshore power for hydrogen production supported by battery. The first 3 scenarios are planned to be studied in detail. The results obtained from such simulation study will guide the exploration of the different options for the last scenarios, e.g. whether to place the battery onshore or offshore. In parallel, a dedicated simulation plan to match the experimental campaign of Result 5 for individual component model validation has been considered. The KPIs will range from purely technical (e.g. the amount of hydrogen produced), to techno-economic (e.g. levelized cost of electricity/hydrogen, LCOE/LCOH), and possible economic profit of the energy hub assuming certain market assumptions.

All partners agree on the selected scenarios, employed models and computational methods, and the proposed approach of the simulation study. Therefore, this activity can be considered successfully completed.

Activity	*Activity 4.2. Dynamic modelling of SENSE Hub concept (Duration: M9-M24)*	
Start-/end date	*October 2023 to January 2025*	Status: *Ongoing*
The main elements of the proposed scenarios have been implemented in the computational framework. This included tailoring or extending existing TNO models (e.g. electrolyser, pipeline and battery models) to the need of the project and implement the selected energy configurations. The logic of operations (how the generated power should be distributed across the energy components, taking into account boundary conditions and operational constraints) has been defined, and implemented for most of the asset configurations. Initial results for the power generated by offshore solar park and wind farm in one year (with hourly resolution) have been obtained (for a location and a representative year). The power generation simulations will be further performed for the other location and years and they will represent the boundary conditions for the downstream components (e.g. electrolyser, battery). Preliminary simulations to test/debug the complete computational models, i.e. a simulation of the entire asset configuration, are ongoing. Preliminary results will be soon presented and discussed with the consortium partners to gather feedback and move forward in the scenario simulations.		

Activity	*Activity 4.3. Model validation based on field testing (Duration: M9-M24)*	
Start-/end date	*October 2024 to January 2025*	Status: *Not started*
This activity has not yet started.		

Activity	*Activity 4.4. Optimization of the SENSE Hub concept at kW scale (Duration: M24-M42)*	
Start-/end date	*January 2025 to January 2027*	Status: *Not started*
This activity has not yet started.		

Activity	*Activity 4.5. Translation to offshore conditions and scale-up to MW pilot (Duration: M24-M42)*	
Start-/end date	*January 2025 to July 2026*	Status: *Not started*
This activity has not yet started.		

Result 5. SENSE Hub Concept has been validated in the extensive land tests at TNO SWITCH Lab

Activity	*Activity 5.1. Experiment plan development and scenario definition (Duration: M1-M12)*	
Start-/end date	February 2023 to January 2024	Status: *Ongoing*
In parallel with the scenario development in Activity 4.1, a set of scenarios dedicated to the extensive onshore tests at TNO's SWITCH field lab has been defined. These scenarios have been aligned with the modelling efforts of Result 4 to ensure the developed SENSE Hub Concept can be validated in the land tests as best as possible. A draft version of the land tests (SWITCH) specific scenario set was presented to the partners in one of periodical consortium meetings, and has now been finalized based on their review.		

The experiment plan is currently under development based on the outcome of the scenario development, and is expected to be finalized by the end of M12.

Activity	*Activity 5.2. Characterization of combined wind and solar generation profiles (Duration: M1-M18)*	
Start-/end date	*February 2023 to July 2024*	Status: *Ongoing*
Both the wind turbines and solar PV systems at the SWITCH field lab are operational, and measurements of the combined generation profile has started around M4. All gathered data is stored both locally and in a TNO managed database. This activity is expected to finish as planned in M18, and the resulting dataset will be used to inform the modelling effort of Result 4, as well as the further experiments in Activity 5.3.		

Activity	*Activity 5.3. SENSE Hub extensive land testing and scenario validation (Duration: M9-M42)*	
Start-/end date	*October 2023 to July 2026*	Status: *not started*
This activity has not yet started.		

Result 6 SENSE Hub Concept has been simulated offshore at MW scale

Activity	*Activity 6.1. Prepare the test plan (Duration: M12-M18)*	
Start-/end date	*January 2024 to July 2024*	Status: *Not started*
The initial testing considerations are included.		

Activity	*Activity 6.2. Dynamic power profile test scenarios (Duration M19-M26)*	
Start-/end date	*August 2024 to March 2025*	Status: *Not started*
This activity has not yet started.		

Activity	*Activity 6.3. Data gathering and analysing during pilot operation (Duration M19-M26)*	
Start-/end date	*August 2024 to March 2025*	Status: *Not started*
This activity has not yet started.		

Result 7. A legal framework has been developed with a suggested approach for implementing SENSE Hubs on a GW-scale

Activity	*Activity 7.1. Overview legal regulatory framework (Duration: M1-M12)*	
Start-/end date	*February 2023 to January 2024*	Status: *Ongoing*
Research was conducted on the applicable legal frameworks from environmental and energy law perspectives. Specific attention was paid to the offshore application of these regulations. Since new laws and regulations for environmental law came into force on January 1, 2024, the study was updated accordingly. For the purpose of the study, consultations were held with Oceans of Energy and Ventolines last year. The study is being finalized for delivery.		

Activity	*Activity 7.2. Legal alignment and agreements with other offshore infrastructure (Duration: M1-M24)*	
Start-/end date	*February 2023 to January 2025*	Status: *Ongoing*
Research is started based on the results of Activity 7.2.		

Activity	*Activity 7.3. Obtaining government approvals and legal impact ecology (Duration:M12-M48)*

Start-/end date	*January 2024 to January 2027*	Status: *Not started*
This activity has not yet started.		

Result 8. A techno-economic system design has been made for optimal system integration of offshore energy components at the GW-scale and has been tested via dynamic modelling

Activity	*Activity 8.1. Definition of challenges at GW scale and scenarios to simulate (Duration: M24-36)*	
Start-/end date	*January 2024 to January 2026*	Status: *Not started*
Internal discussion at TNO to get informed on scenarios that will be considered in other projects (e.g. North Sea Energy programme) and understand the envisioned business model for a future energy hub. No technical activities started yet.		

Activity	*Activity 8.2. Evaluation via dynamic modelling (Duration: M36-48)*	
Start-/end date	*January 2026 to January 2027*	Status: *Not started*
This activity has not yet started.		

Activity	*Activity 8.3. Techno-economic considerations for subsea infrastructure (cables/pipelines) (Duration M24-M48)*	
Start-/end date	*January 2025 to January 2027*	Status: *Not started*
This activity has not yet started.		

Activity	*Activity 8.4. Design of the electrical infrastructure for SENSE Hub Concept at GW scale (Duration M24-M48)*	
Start-/end date	*January 2024 to January 2027*	Status: *Not started*
Initial discussion took place among the partners involved in the task and the preliminary considerations are aligned among the participants.		

Project Coordination and Project Management

Activity	*Activity 1. Legal, administrative and financial management (Duration M1-M48)*	
Start-/end date	February 2023 to January 2027	Status: *Ongoing*
The Consortium Agreement was established and ongoing monitoring of project progress is taking place.		

Activity	*Activity 2. Technical project management (Duration: M1-M48)*	
Start-/end date	*February 2023 to January 2027*	Status: *Ongoing*
A project SharePoint site was established to facilitate collaboration. The Project Execution Plan was developed and send for review to all consortium partners. Technical management continued throughout the period including identifying and managing project risks, producing, reviewing and approving project documents. Period meetings are established – every 2 months a technical meeting and every 4 / 5 months a consortium face to face meeting. Next to this ad hoc meetings are taking place to cover specific topics.		

Activity	*Activity 3. Advisory board engagement (Duration: M1-M48)*	
Start-/end date	*February 2023 to January 2027*	Status: *Ongoing*
See description Result 9		

Result 9 All stakeholders are identified, informed and regularly engaged with through a variety of communication and dissemination tools and channels

Activity	*Activity 9.1. Dissemination, communication (Duration: M1-M48)*	
Start-/end date	*February 2023 to January 2027*	Status: *Ongoing*

A successful first stakeholder meeting was organized in summer of 2023. The stakeholder plan is ready and has been reviewed both internally and by the consortium. The main elements for stakeholder engagement are:

	Goal	Period
Stakeholder meeting 1	Informing stakeholders on project activities and gathering their input. Identifying stakeholder needs and threats and opportunities.	May 2023
Stakeholder meeting 2	Sharing intermediate results and more information on the next project activities.	Q4 2024
Stakeholder meeting 3	Sharing the final results and discuss the implications together with stakeholders.	Q4 2026

Stakeholder newsletter
Shared 1x per year and provides an overview of relevant results and developments.

Summary for policymakers
Drafted at the end of the project and provides an overview of results and findings. In addition, it will also include recommendation based on stakeholder needs.

The upcoming second stakeholder meeting will likely be held in Q4 of 2024.

3 Results achieved per milestone

Milestone 1 Design of the 160 kW optimized offshore solar extension is completed Procurement and Construction activities can start.	**M15**
Connected/Achieved results: Milestone 1 is strongly connected to Result 1. The optimized design is based on NS2 pilot data. Motivation: The completed design is a Milestone as it represents an important step for Result 1.	Completed (April 2024, M16)
Milestone 2 The extension of the offshore solar (optimized 160 kW) was installed offshore and was put in operation. Data is collected for validation of improvements.	**M42, not due in this reporting period**
Connected/Achieved results: Milestone 2 is one of the most important milestones in the project and it shows that Result 1 of the project was achieved. Achieving Milestone 2 implies succeeding in completing the activities under Result 1, and achieving the stated performance targets of the system. Motivation: Operational extended optimized offshore solar floating is a big Milestone for the project addressing the main MOOI goals 1 and 2 for Innovation theme 2.	
Milestone 3 3D hydrodynamics-ecosystem model has been validated with field data.	**M39, not due in this reporting period**
Connected/Achieved results: In order to achieve the Milestone 3, multiple activities need to be successfully completed: e.g. development of the model and collection of field data. By using the validated model, predictions of effects at larger scale can be made. Motivation: Milestone 3 represents the successful completion of Result 2 leading to further understanding of the environmental limits of floating solar parks.	
Milestone 4 The understanding of the cumulative effects of offshore solar wind through validated models.	**M42, not due in this reporting period**
Connected/Achieved results: Milestone 4 represents the end of Result 3 an important achievement of the complete project. Motivation: International guidelines and national legal frameworks determine that offshore energy generation has to be within accepted limits of ecological space. This milestone is a crucial element in the roll-out of large-scale offshore solar within wind farms.	
Milestone 5 The dynamic model of the SENSE Hub concept has been developed, validated and runs simulations for accelerated testing.	**M42, not due in this reporting period**
Connected/Achieved results: Milestone 5 represents the end of Result 4 an important achievement of the complete project. Motivation: Milestone 5 represents an important pillar in development of the project. By reaching this milestone, multiple research questions are answered, and an optimal SENSE Hub concept is identified.	

Milestone 6 Onshore testing experiment plan and scenario definition completed.	**M12, January 2024**
Connected/Achieved results: SENSE Hub concepts scenarios are defined and modelled for onshore testing. This represents the starting point in extensive land testing and in understanding the limitations and opportunities in running the SENSE Concept. Motivation: Issuing and approving the land test plan and scenario definition it is an important step in extensive land testing campaign.	Completed
Milestone 7 Onshore testing and scenario validation completed.	**M36, not due in this reporting period**
Connected/Achieved results: Milestone 6 marks the end of Result 5 of the project. This is an important milestone as the consortium will understand the opportunities and challenges in running SENSE Hub concept on land. The results of the extensive tests will be further fed into Result 8. Motivation: The learnings of achieving Milestone 6 will allow the continuation of the project and will feed data for the scale up assessment of SENSE Hub Concept.	
Milestone 8 The legal framework for SENSE hub has been developed with clear recommendations for GW scale implementation.	**M48, not due in this reporting period**
Connected/Achieved results: Milestone 8 marks the end of Result 7 of the project. This is an important milestone as the consortium will understand legal framework in developing SENSE hubs at GW scale, including the regulatory framework for the complete concept, the opportunities and challenges in cable pooling and understanding of the governmental permissions. Motivation: The learnings of Milestone 8 are not only relevant for SENSE hub consortium partners but also for the project identified stakeholders.	
Milestone 9 A techno-economic system design has been made for optimal system integration of offshore energy components at the GW-scale.	**M48, not due in this reporting period**
Connected/Achieved results: Milestone 9 marks the end of Result 8 of the project. This is an important milestone as the consortium will understand the technical and economic challenges and opportunities in developing SENSE hubs at GW scale. Motivation: The learnings of Milestone 8 are not only relevant for SENSE hub consortium partners but also for the project identified stakeholders.	

4 Bottlenecks

Limited water samples available for turbidity and fluorescence sensor calibration due to limited weather windows for sample collection (activity 2.1)

- Result, reasonable sensor calibration not yet possible
- Solution, collect more samples in 2024

Connection off offshore solar pilot to offshore energy hub

- Result, for the purpose of result 6, a physical electrical connection between the offshore solar pilot and the offshore wind + hydrogen pilot are preferred. Currently, this infrastructure is not yet developed.
- Solution, (1) Campus@Sea is a dedicated organization that is focusing on securing a grid connection between the Offshore Test Site (location NS2 pilot) and the Neptune Q13a production platform (location PosHydon pilot); the organization has secured funding through Kansen voor West III and aims to realize the connection in Q3-2024; if not realized, (2) an alternative would be to use the OOE pilot at Hollandse Kust Noord windfarm in which OOE is part of the innovation scope and implements a 0.5 MW offshore solar pilot in 2025-Q2 that is connected to a Baseload Power Hub that is similar to a North Sea Energy Hub (with offshore hydrogen, storage, and offshore wind energy profiles

5 Sense Hub contribution to the MOOI scheme objectives

SENSE Hub Project contributes to **MOOI mission A** – Electricity, and more specifically to Innovation **Theme 1** "Innovations as an integral part of offshore wind energy on North Sea" and **Theme 2** "Innovations for floating solar parks in the North Sea".

Innovation Theme 1 - SENSE Hub will contribute to a more affordable, a more spatial inclusive, and a more stable energy system within the offshore wind energy plans by optimizing various energy systems integration at North Sea energy hubs. The intermittence of solar is used as a hedge against the disadvantages of the offshore (wind) energy developments that are solely based on the intermittence of the wind. Solar contributes both seasonally as well as daily to a more complementary and stable energy pattern. This can result in 1) increased affordability of the offshore energy infrastructure (by means of higher utilization, output per investment increases) and 2) higher reliability (less weather-dependent energy generation). Moreover, the limited offshore space for offshore wind can be utilized (multi-use of the sea space as well as export cable, pipeline, and landfall space) and possible cumulative effects of the combination of wind + offshore solar may result in positive environmental merits. The SENSE Hub will validate the concepts / hypotheses by focusing on the understanding of the technical, economic and ecological implications.

Innovation Theme 2 – To enable the contributions at Innovation Theme 1 to act impactful, developments are required at offshore solar technology. These are mostly related to necessary cost reductions and increased lifetime reliability. Furthermore, environmental impacts (negative and positive) are largely unknown at sea and require further assessment (incl. as cumulative to offshore wind environmental effects). In SENSE Hub, the consortium will build on the learnings from NS2 DEI+ project and extend the solar park of Oceans of Energy focusing on a new design loop for an improved / cheaper offshore solar array with improved technical reliability. Pilot is furthermore monitored for environmental effects, which are used to feed into model developments for the assessment of environmental impacts of large-scale applications.

6 Spin off inside and outside the sector

During the reporting period no spin off or spin out results have been obtained.

7 Overview of public publications on the project and where they can be found or obtained

Date	Publicity title	Publisher
28/02/2023	*SENSE Hub Press release*	*Consortium*
28/03/2023	*Presentation on the project on the Energy Reinvented Community regarding wind and floating solar innovations*	*TNO*
15/03/2023	*Energeia.nl article – TNO onderzoekt inpassing offshore wind in energiesysteem- link*	*TNO*

Date	Publication title	Publisher
20/11/2023	*Pitch SENSE Hub - Johnny Meit, Oceans of Energy - onderdeel van podcast #ditisonzetijd: Groen waterstof op zee voor verduurzaming industrie vanaf min 29:30 - Link*	*TNO*
Publications not directly related to SENSE Hub but related to Offshore solar environmental research		
April 2023	Peer reviewed article in Sustainability – Vlaswinkel et al. Environmental Observations at the First Offshore Solar Farm - Link	*OOE*
Dec 2023	Peer reviewed article in Frontiers in Marine Science – Mavraki et al. Fouling community composition on a pilot floating solar-energy installation in the coastal Dutch North Sea - Link	*OOE*

8 Contact

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