SwitcH2 B.V.
SeaWater into Clean Hydrogen

Progress report year 1

OFFSET

Offshore Floating Storage of Energy and Transfer

Main applicant:	SwitcH2 BV
Partners:	TU Delft, BW Offshore Management BV, MARIN, Strohm BV
Program:	MOOI
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Project title:	OFFSET (Offshore Floating Storage of Energy and Transfer)
MOOI Mission:	A, Electricity
Specific theme:	“Innovations as integral component of wind energy areas on sea”
Date of this report:	01 March 2024
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1 Project Summary

Background

In order to meet the climate goals of 2030 and 2050, the deployment of (offshore) wind farms will need to increase. It is projected that the Netherlands will produce 43 GWh of energy through offshore wind deployment by 2050. However, generating this amount of energy through renewable energy sources such as wind comes with several obstacles, due to the variability caused by weather dependence and the limited capacity of the grid. It is inevitable that periods of surpluses and scarcity will alternate if these obstacles are not addressed, causing further grid congestions and losing valuable energy. At the same time, the Netherlands is facing the challenge of physical scarcity, especially in relation to offshore wind farms to be deployed at the North Sea.
Several solutions are being developed today to overcome these challenges and obstacles, among which the conversion to energy carriers such as hydrogen and ammonia. These can store the valuable energy in order to stabilize and increase the overall efficiency of the grid. Additionally, producing energy carriers at the source of the renewable energy brings on further savings and advantages compared to land-based production of such energy carriers. Yet, these renewable fuels as energy carriers are still not competitive due to high prices and require significant infrastructure to be implemented efficiently.

Purpose of the project

The purpose of the project is to develop an overall integrated system in which the infrastructure for hydrogen and/or ammonia are included, which will revolutionise the way in which the offshore wind sector and relevant (energy-intensive) industries currently operate. This system is called OFFSET: Offshore Floating Storage of Energy and Transfer. We will develop a floating hydrogen and/or ammonia production and storage facility that is connected to an adjacent wind farm and that will operate continuously. The produced hydrogen can be transported to shore through existing oil and gas pipelines, whereas the produced ammonia can be transported to end-users by shuttle tankers. This easily scalable solution will decrease the cost of green fuels and thereby increase their accessibility. The aim is to provide a flexible solution that answers to the needs of the global energy transition and corresponding scenarios regarding energy carriers. During the project, the production of hydrogen directly from seawater is being researched in order to provide a long term strategy for increasing efficiency and affordability.
Finally, the project aims to secure energy supply, increase the competitiveness of hydrogen and ammonia as green fuels, and facilitate the road to zero emissions, while taking away the pressure on (seabed use at) the North Sea.

Results

At the end of the project, the consortium will have developed a viable technical and economic solution which can be realised and which van be made visual by means of a small-scale model (1:50) of the OFFSET facility for testing in the offshore basin of MARIN. Additionally, a thermoplastic composite pipe

for transferring hydrogen and offloading and bunkering of ammonia will be developed, as well as engineering design plans of the OFFSET facility, safety roadmaps, and a lab validation of direct seawater electrolysis. The results will allow the first OFFSET facility to be operational by 2030. For the longer term, by 2035, it is expected that the first OFFSET facility with direct seawater electrolysis will be implemented.

The consortium will actively involve stakeholders from different sectors, such as energy companies, wind farm operators, wind farm developers, ammonia production projects, and energy-intensive industry sectors. These stakeholders all have a commercial interest in more accessible hydrogen and ammonia at lower prices, as well as energy grid optimizations and the other benefits that the overarching OFFSET system represents.

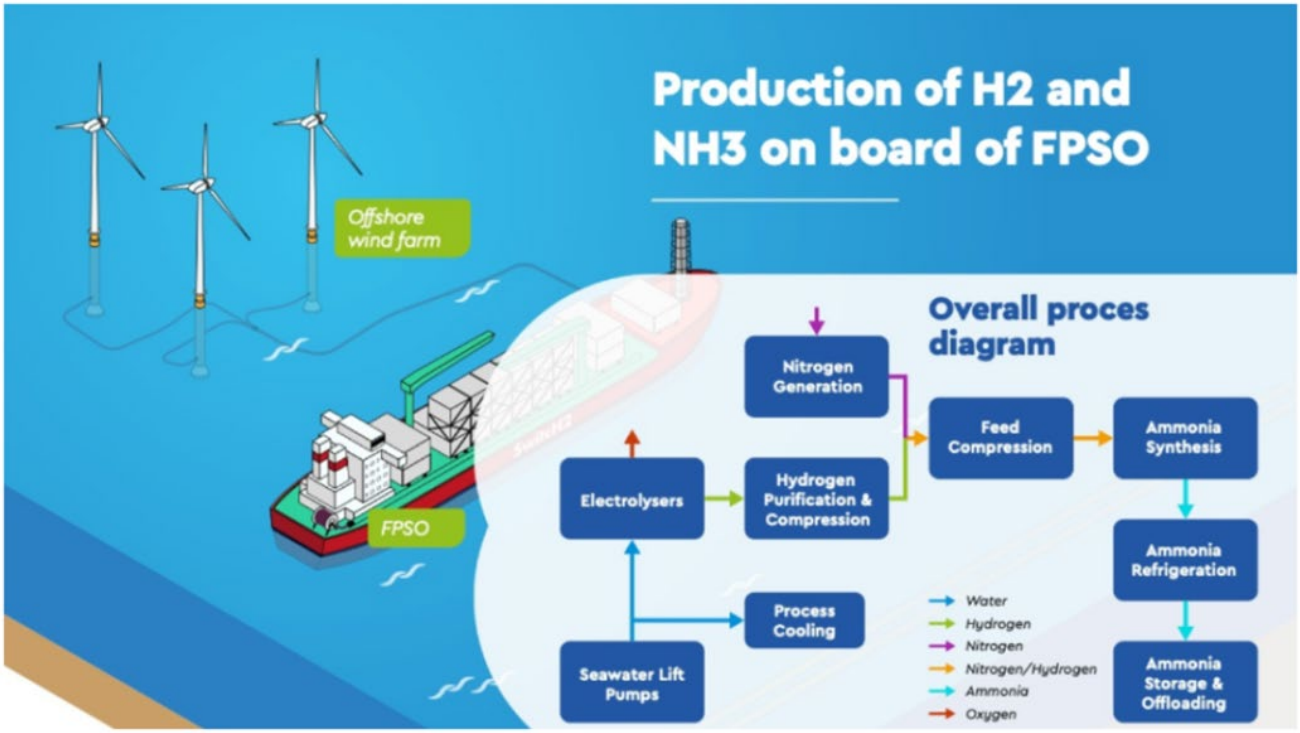

Figure 1: SwitcH2, graphic representation of the OFFSET solution

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2 Project activities

The entire project is a result based. The project is developed to realize the different results during the project. Per result different activities are planned.
Currently we just finished year 1 of the project (march 2023 to march 2024).

Result 1: Proof-of-concept of direct seawater alkaline electrolysis
Start (actual): 01-03-2023
End (planned): 28-02-2027
Involved partners: MARIN and TU-Delft

Current status: ongoing as planned

Description:
This result refers to a proof-of-concept (lab validation) of a novel method to convert direct seawater into hydrogen. This result and process technology can consequently be integrated in an electrolyser.
Tangible outcomes of this result are:

- Recipes for catalyst material selective for water splitting and preventing oxidation of other inorganic ions in seawater
- Developed thin-layer coated Ni-based electrodes
- Validated process scheme with bipolar membrane-controlled seawater pH for direct electrolysis
- Method (optimized process parameters) for in-situ re-generating catalyst via alternating-current electrodeposition

Result 2: Research results of marinization of floating production of green fuels
Start (actual): 01-03-2023
End (planned): 01-03-2025
Involved partners: MARIN and BWO

Current status: ongoing as planned

Description:
Subresult (1) Hydrodynamic study | The objective of this study is to understand the several water motions. **Tangible outcomes** of this result is a report with calculated yearly power output of the OWC specifically and generally a water and vessel hydrodynamic motions report. The corresponding activities will be carried out by MARIN, with their extensive expertise on offshore modelling and hydrodynamic studies.
Tests with a preliminary design of the hull including two integrated oscillating water column wave energy converters (OWC WECs) were performed in MARIN's Shallow Water Wave Basin. Tests focused

on the vessel motions and the OWC WEC power output in varying sea states. The experimental results have been reported and are used for validation of the numerical modelling in activity 2.1.

The **means of verification** are the calculations of the OWC, validated with the basin test data, which will result in a quantification of the yearly energy output of the OWCs integrated into the floating facility. This will provide input for activity 2.2, 4.3, 5.1 and 5.2.

Subresult (2) Study on marinized designs | BW Offshore has an established track record of delivering offshore floating production vessels, supplied with production technology designed for an offshore environment. In the case of hydrogen and ammonia production, plants have only been installed onshore, therefore further study is required to quantify the differences in design for offshore enviroment. The **tangible outcome** is a marinized design study, which will involve identifying design and cost impact on material selection for onshore vs. offshore hydrogen and ammonia plants and general topside configurations and equipment. Several larger pieces of equipment such as separators and reactors will be analysed for selection of more space efficient offshore design. This result does not include fluid flow studies of the hydrogen or ammonia itself (for hydrogen fluid studies in offshore floating environment, see activity, and for ammonia or other energy carrier fluid studies, see paragraph 3.3.2), but rather focuses on mapping the right equipment and material configuration for offshore floating conditions. The **means of verification** of this subresult exists out of the results of Activity 4.3.

Result 3: Validation of thermoplastic composite pipes for OFFSET
Start (actual): 01-12-2023
End (planned): 31-12-2026
Involved partners: Strohm BV

Current status: ongoing as planned

Description:
This result refers to the engineering plans and overall validation of the use of thermoplastic composite pipes for the OFFSET facility. Hydrogen and ammonia production at and export from offshore floating facilities, requires a dynamic fluid conduit/riser that transfers the hydrogen from the floating facility to the static seabed. Dynamic riser technology used in the oil & gas industry (unbonded flexible pipe) is not qualified for use with hydrogen and has issues with hydrogen embrittlement in the metallic armouring due to fatigue loading in an hydrogen environment. Thermoplastic Composite Pipe (TCP) is flexible, manufactured in long lengths and non-metallic, eliminating the hydrogen embrittlement issue. The offloading of ammonia to shuttle tankers requires a (temporary) flexible pipe connection of the FPSO to a shuttle tanker, capable of transferring the entire cargo volume of ammonia to the shuttle tanker in a short (<24hrs) time frame. To date, TCP is used in static and semi-dynamic and temporary applications (jumpers) in typical oil and gas service. To enable the application of TCP for hydrogen

risers and ammonia offloading, TCP materials design properties need to be established for the relevant conditions, i.e with hydrogen and ammonia.

Tangible outcomes of this result are material and pipe test results and detailed engineering plans. **The indicators** that will allow to measure this result are a technically feasible TCP riser configuration that fulfills the pressure, temperature, flow and design life requirements of the OFFSET facility in the (assumed) environment. The indicators can be measured, i.e. the technical feasibility of the TCP riser system shall be confirmed by the basin model test at Marin (result 6).

Furthermore, a proof-of-concept integration of fibre optic data communication with TCP will be delivered. The succes of this proof-of-concept will be measured by a mechanical test of the prototype and assessment of the potential and requirements to scale up the solution to project/industrial application.

Result 4: Basic design OFFSET with integrated equipment
Start (actual): 01-12-2023
End (planned): 28-02-2027
Involved partners: SwitcH2, TU-Delft and BWO

Design and selection of battery system	TU Delft
Process design	SwitcH2
Structural design engineering plans/reports	BWO
HAZID/HAZOP safety reports	SwitcH2

Current status: ongoing as planned

Description:

This result refers to the engineering plans for the OFFSET facility, in which all equipment is integrated, also based on the outcomes of result 3. Tangible outcomes of this result are detailed engineering plans that will allow for the direct implementation of the OFFSET facility.

Subresult (1) Continuous Energy Supply, responsible during project: TU-Delft
Subresult (2) Process design, responsible partie during the project are SwitcH2 and BWO
Subresult (3) Structural design, responsible partie during the project is BWO
Subresult (4) HAZOP and HAZID safety analyses, responsible partie during the project is SwitcH2.

For every sub result a specific activity is planned (4.1.-4.4.)

Result 5: Small-scale operational prototype OFFSET
Start (actual): 01-03-2023
End (planned): 28-02-2027
Involved partners: MARIN, SwitcH2

Current status: started

Description:
This Result was planned towards the end of the project, A physical scale model of the hydrogen production unit (final design) will be tested in MARIN's Offshore Basin.

MARIN was able to start the planned work under this WP from the start of the project. Steps are taken on improving the digital as well as the physical model of the OWC chamber solution under activity 5.1. Currently a digital model is being validated based on the simulation and comparison with actual scale model tests in the Marin basin.

Result 6: Enabling supporting actions (other project activities)
Start (actual): **01-03-2023**
End (planned): **28-02-2027**
Involved partners: SwitcH2

Current status: ongoing as planned

Description:
The enabling, other project activities are planned to be carried out under this result. This includes both project management activities as well as knowledge dissemination activities, which are of crucial importance to a succesful project execution.

The project is now running for a full year and did not yet finalize any of the planned results. It is too soon for these. Activities did start as planned and yielded different sub-results (such as a hydrodynamic study).
A detailed overview of all activities is not part of this public report.

3 Challenges and project perspectives

Currently there are no specific challenges that hamper or delay the project. The perspective for future use of this solutions has improved during the first year of the project. The need for additional solutions within the offshore wind industry that don't use cable arrays and do not further stress the already limited energy distribution network (power cables) has a good market potential. Furthermore there are incentives being deployed to stimulate the production of green hydrogen (subsidy on prices in order to compete with current gray/blue solutions).

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4 Contribution to the MOOI-mission:

Firstly, this project will contribute to the overall mission statements of the MOOI-mission A, Electricity. It answers to all identified challenges in relation to the upscaling of wind and solar energy on either sea or land:

Mission A challenge	OFFSET solution
Energy production needs to become more affordable	OFFSET offers the solution for a greater yield from offshore wind farms and therefore also the affordability of wind energy by providing flexbility to the overall wind energy system. It also produces green hydrogen. This flexibility is necessary to cope with the challenge of fluctuating energy production. OFFSET will use a neighbouring wind farm's energy supply to power the constant production of renewable energy carrier hydrogen, combined with the on demand production of ammonia. This will significantly reduce the peaks and lows within the wind energy supply and thereby increase the accessibility and affordability, as more supply can be ensured against a relatively low investment cost at systems level.
There is a scarcity of both land and sea	OFFSET will produce its hydrogen and ammonia offshore on an FPSO. Electrolysers can be stacked onboard and with the most efficient engineered design of the OFFSET, and already a 300 MW capacity will be possible on only one unit. This represents a huge capacity while consuming little space in comparison to other energy production solutions. Due to its integration with a wind farm and the size of only one or several OFFSETs are needed, no excessive maritime spatial planning is required.
Integration in the Dutch energy system is complicated	The OFFSET concept will make integration of produced wind energy in the Dutch system more accessible through the implementation of the renewable energy carriers hydrogen and ammonia. These can be transported to shore for electrification or direct implementation in industries.
Sustaining the environment and ecology of the North Sea	Primary threats to the North Sea ecology include pollution and resource exploitation such as gas and oil. The OFFSET facility will not extract any resources except for seawater for the electrolysis process and produce no greenhouse gas emissions that contribute to ocean acidification. The OFFSET project will take into account the risk of extracting seawater and consequently the risk of extracting fishes or other species. Further, the OFFSET facility will use existing pipelines where possible for the transportation of hydrogen, which will avoid constructing new infrastructure in the already occupied North Sea region, and thereby refrains from adding more pressures on the ecology and environment.

Table 1: The contribution of the OFFSET solutions to MOOI Mission A, Electricity.

The project fits within the MOOI mission A; Electricity.

The accompanying goal of this mission A is to stimulate the innovation themes that can lead to a first implementation within 10 years (before 2032) and can contribute to affordable, trustworthy, clean and safe energy supply. The OFFSET project answers to this goal by bringing hydrogen production to a high and cost-efficient level, consequently providing solutions to flexibility in the energy grid that increases the trustworthiness of the overall energy system level. With the current project planning, it is expected that the first OFFSET facility will be operational in 2030. This answers to the MOOI mission of implementing these innovations before 2032.

Secondly, this project will contribute specifically to the first innovation theme that belongs to this mission, "Innovations as integral component of wind energy areas on sea". The overall OFFSET system is especially related to this innovation theme through focus on trustworthiness, flexibility, security of supply, and safety of the energy system. This is because it combines the wind energy production with the conversion and storage of hydrogen and ammonia. The OFFSET concept involves a system approach, as it brings not only innovative solutions to the production of hydrogen through direct seawater alkaline electrolysis, but combines this with the conversion to ammonia, the bunkering or offloading through thermoplastic composite pipelines, their transportation to shore through existing oil and gas pipelines, and the exploitation that follows. Innovations are taking place at all levels of the renewable energy system, while making optimal use of the available space. One OFFSET can already have a 200 MW capacity and thereby takes up relatively little space when integrated in a wind farm. The OFFSET solution will have a capacity of 300 MW.
Additionally, the OFFSET project takes into account the protection of the North Sea and its ecology. The North Sea is an extremely occupied area full of economic activities, such as maritime transport, fisheries, wind farms, and resource extraction facilities. Due to the foreseen increase of wind farms in the future to achieve the climate goals, the North Sea will only become more occupied and the pressures on its ecology will only increase. The OFFSET project approaches these pressures holistically, by being a zero emission facility that requires relatively little space and does not require the construction of new infrastructure.

5 Spin off of the project within and outside the offshore energy sector

As the project is now running for just 1 year it did not yield any tangible spin off yet.

6 Dissemination of results, and project publications

On the dissemination of the results SwitcH2 participated actively in articles and interviews on project OFFSET which have been published on social media and in cooperation with RVO.

- Post from RVO on the RVO site and LinkedIn "Met drijvende productieplatforms willen we groene waterstof op zee produceren" (rvo.nl)
- Publication: Groene waterstof maken met hulp van offshore windenergie en zeewater | Windenergie Nieuws (windenergie-nieuws.nl)

Press release via RVO on Windpower.nl

- Via Wendy Laursen in the Motorship June 2023 – Switch 2 Offshore
- Via ThyssenKrupp PR on LinkedIn https://www.linkedin.com/posts/thyssenkrupp_kooperation-f%C3%BCr-schwimmende-gr%C3%BCne-ammoniakanlage-activity-7092789232447959040-Gr1q?utm_source=share&utm_medium=member_desktop
- Via TU-Delft on their web-site: https://www.tudelft.nl/en/2023/h2-platform/mooi-grant-for-a-floating-green-hydrogen-and-ammonia-project

The RVO-publication is attached to this report as an annex.