Sustainable Installation of XXL Monopiles (SIMOX)

Public Annual Report SIMOX

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Non-CONFIDENTIAL

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The SIMOX project is part of the GROW programme on offshore wind energy. The GROW programme aims to reduce levelised costs of offshore wind electricity, to create added value for the Dutch economy and to strengthen the Dutch offshore wind industry. (www.grow-offshorewind.nl)

SIMOX is supported with a Topsector Energy subsidy from the Dutch Ministry of Economic Affairs and Climate Policy, administered by Netherlands Enterprise Agency (RVO). The specific subsidy concerns the 2020 MOOI-subsidy round.

Het SIMOX project is uitgevoerd met Topsector Energie subsidie van het Ministerie van Economische Zaken en Klimaat, uitgevoerd door Rijksdienst voor Ondernemend Nederland. De specifieke subsidie voor dit project betreft MOOI-subsidie ronde 2020.

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1 SIMOX Project outline

1.1 Motivation

Monopiles are by far the most commonly used foundations for offshore wind turbines in the North Sea and it is expected to remain so in the future. Monopiles are straightforward to fabricate, relatively inexpensive to manufacture, use less space on transport vessels, and are reliable. The dominant method used now to drive monopiles into the seabed is the hydraulic impact piling (hammering). The big disadvantage of the impact driving method is the generation of underwater noise that can be detrimental to fauna and that the method is not suitable for extracting piles again at the end of the lifetime. Alternative installation technologies are being researched, developed, and tested at various Technology Readiness Levels (TRLs). However, none of these technologies has reached a TRL that makes it a preferred/ready solution for the installation of future XXL monopiles under a broad range of soil conditions. With a better understanding of their performance and a validation of the underlying models, the development of these technologies can be enabled, which should ensure that offshore wind remains one of the lowest-cost, electricity generation options for the North Sea.

1.2 Objective of the project

The SIMOX consortium will develop new and necessary technical and environmental knowledge with the target to ensure that within 5 years one or more qualified and validated next-generation installation technologies will be available. Such technologies should enable the installation (and decommissioning) of XXL monopiles for offshore wind turbines with large (>10 MW) energy yield in a sustainable, cost-effective, societally and environmentally acceptable manner. SIMOX will research and test the following installation technologies with different TRLs and different gaps in knowledge:

- Vibro: Vibratory driving with a purely vertical excitation;
- GDP: The Gentle Driving of Piles concept, which is an emerging technology that combines a vertical vibratory excitation with a high-frequency torsional shaking;
- JET: Aiding vibratory techniques by fluidising the internal soil column in the pile;
- BP: Modifications to the conventional impact driving which reduces noise (blue piling principle); and
- DECOM: Pile extraction technologies that make use of vibration or pressure.

SIMOX aims to bring the required knowledge for these options on par with each other.

1.3 Result

The major deliverable of SIMOX is an improved insight in, and understanding of the physics behind several promising, innovative, affordable, reliable, and sustainable technologies for the installation (driving) of XXL monopiles, as well as decommissioning. Another important result of SIMOX - as a spin-off from the broader GROW consortium - is the formation of an ecosystem where companies, research institutes, NGOs and authorities get to know and use each other's strengths even better, for the social challenge of developing sustainable energy means of wind at sea and to remove any obstacles to this. This has added value both inside and outside this project.

The SIMOX project should lead to the following results:

a. High-quality experimental data set and validated pile driving model(s) with as new element the refusal depth prediction in dense sands, stiff clays and layered soils.
b. Noise prediction model(s) that are able to provide noise levels and frequencies at 750 m from the source. An assessment of the noise mitigation potential / effort for the different technologies and recommendations for implementation of the results in future guidance to be developed by regulators.
c. High-quality experimental data set from laboratory and scaled field tests and model(s) for predicting the lateral bearing capacity for piles installed by vibro-technology, compared to Impact driven piles.
d. Proof of concept and experimental data for extraction of monopiles with the aid of static forces combined with vibrating force/jetting.
e. For each installation technology: a concept specification of the future installation tool for the XXL monopile combined with an indication of the area of application and limitations.

f. Alignment for technology qualification of the technology/ies.

Overview of the main results, grouped by main work-package

WP Nr.	Work Package	Main RESULTS, products, and processes (reference to work package)	
1	**Inception phase and R&D groundwork**	**1**	**Technology assessment (1A-1E)**
			Criteria, specifications and future demands as necessary input for the technology testing and validation (design, operational, environmental, etc.).
			State of the art review of (practical) engineering models aimed at prediction of driveability, noise emission and lateral capacity of monopiles driven using vibratory technologies.
			Technology readiness of the technologies for the experimental program.
2	**Pilot projects, data collection**	**2**	**Testing program designed and prepared (2A, 2E)**
		3	**Laboratory datasets (2D)**
			Insights and data set from **scaled laboratory testing (centrifuge & 1g)** installation (driving control parameters and lateral capacity) testing in **Sand & Clay** (offshore representative) of scaled piles.
		4	**Onshore testing datasets (2B)**
			Insights and data set from **onshore** installation (driveability and lateral capacity) testing in **Sand** (offshore representative) of ~2m diameter piles.
			Insights and data set from **onshore** installation (driveability and lateral capacity) testing in **Clay** (offshore representative) of ~2m diameter piles.
		5	**Nearshore testing datasets (2C)**
			Insights and data set from **Nearshore** installation (noise emissions and driveability) testing in offshore representative soil of ~2m diameter piles.
3	**Analysis, integration of results, qualification, and reporting**	**6**	**Driveability prediction model (3B)** Engineering-based and validated model and work-flows for prediction of drivability of XXL monopiles including refusal depth
		7	**Lateral bearing capacity prediction model (3D, 3F)**
			Engineering-based and validated model and work-flows for prediction of lateral bearing capacity of XXL monopiles for the tested technologies
		8	**Noise prediction model (3C,3E)** Validated model and work-flows for prediction of Noise of XXL monopiles for the tested technologies
		9	**Decommissioning strategies (3A)** Report on the potential and/or challenges of using the tested technologies for decommissioning of full monopiles, including possible additional mitigation measures.
0	**Technical project management and result delivery**	**10**	**Integrated result delivery (0,3A,3G,3H)**

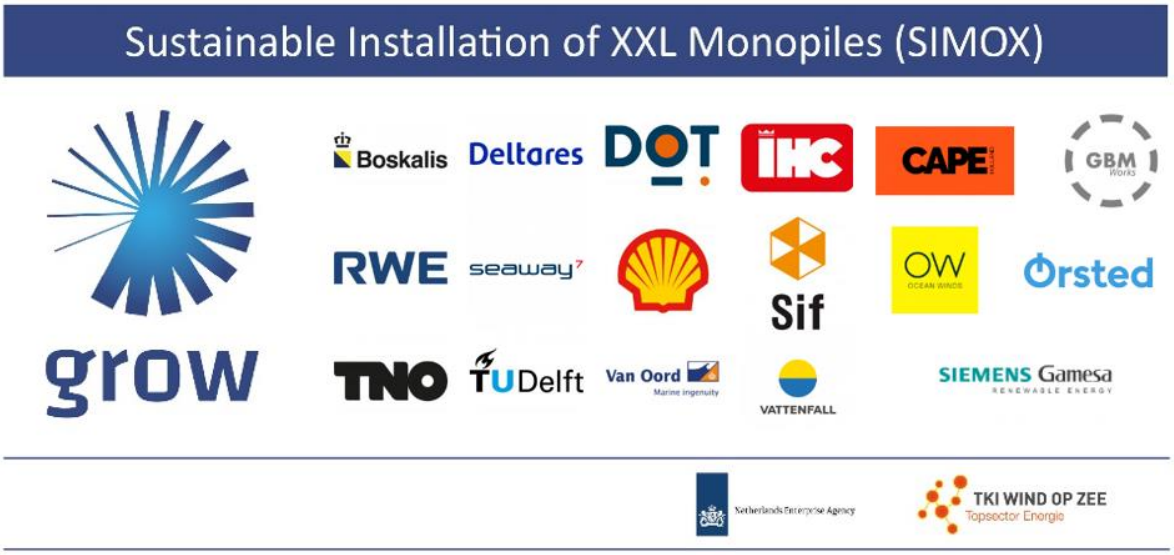
1.4 Short description of the activities

The project starts with identifying a set of criteria to – as much as possible – objectively characterise the various innovative installation techniques subject to research in SIMOX. All partners, with support from NGOs, RWS and a certification body, will provide input to the criteria. Based on this information and a desktop study, we will make an inventory of the state of the art with respect to science and engineering, to identify the gaps in data and models for the new technologies.

Thereafter, we will perform a series of laboratory and field-tests at intermediate scale and generate the data sets that are needed to gain new insights and knowledge, to support model development and validation, and draw conclusions for the design practice. This will also serve as input for further improvement of the technologies. Finally, we will analyse, integrate, and implement the results in prediction models in close cooperation with stakeholders, i.e. clients, designers, certification bodies, NGOs and regulatory bodies. The activities will be carried out in three substantive WPs.

1.5 Project consortium

The project consortium is depicted in the graph below. The consortium includes representatives from project developers (Shell, RWE), contractors (Boskalis, Seaway7, Van Oord), knowledge institutes (Deltares, Technical University Delft, TNO), and OEMs (IHC IQIP, Sif, Delft offshore Turbine, Siemens Gamesa RE, CAPE Holland, GBM Works). In April 2022 three partners joined the consortium: Ocean Winds, Ørsted and Vattenfall (all project developers).



2 Project progress in the reporting period

During the first year of the project, the following progress has been made in achieving the project milestones:

- [General] Three new partners have joined the project (Ørsted, Vattenfall and Ocean Winds). This brings additional funds which will help the project deliver the proposed results and potentially expand the scope, as well as key knowledge and industry experience.
- [WP0][MP9] Based on the outcomes of WP1, a Scope change request has been prepared and submitted to RVO to; Change the onshore testing conditions, change the offshore testing location and update project financing.
- [WP1A][MP1] The technical, ecological and sustainability related criteria relevant for assessing installation technologies have been investigated and defined. This has been completed with input from stakeholders and specialists on all relevant topics.
- [WP1B][MP1] The state-of-the-art of current driveability, noise emission and (lateral) bearing capacity models has been assessed and reported.
- [WP1C][MP1] A study has been completed into the operational, environment and practical aspects of pile installation that should be taken into account when assessing and comparing technologies. This includes a definition of normal operating practices.
- [WP1D][MP1] The direction of future research, modelling and technology development has been investigated, summarised and compared with the objectives and results of the SIMOX project. Research questions that may become of increasing importance have been identified and will be integrated into the test programme as far as possible.
- [WP1][MP1] Work package 1 has been completed (including reporting), achieving MP1 in line with the project plan and schedule.

- [WP2A][MP2] Significant progress has been made in developing an appropriate test plan for offshore, onshore and lab testing activities. This includes definition of test objectives/results, test program, required materials, site selection and planning activities. These plans have been discussed with equipment suppliers and those who will work on the models within the project to ensure full alignment.
- [WP2A][MP2] The project has had some difficulties in selecting a suitable site for onshore testing, due partially to; Lack of geotechnically appropriate locations in NL, High density of development in NL leading to reduced available 'large, open areas'. Measures have been put in place to mitigate this risk and it is expected that a suitable site will be found without harming project outcomes.
- [WP2D][MP3] Experimental work in the water-soil flume of Deltares has been started based on the programme developed in WP2A.
- [WP3B-E][MP6-8] Work has begun on all three main models of the project (lateral capacity, driveability, noise emissions). Potential setups for these models have been assessed and initial modelling work carried out for some of these. Feedback from the modelling process has been integrated into the design of the lab, offshore and onshore test programme design to ensure maximum synergy between these activities.
- [WP3F][MP7] DNV has been contacted and constructive discussions have taken place on the technology qualification of a lateral bearing capacity model for vibro-installed monopiles. As part of the technology qualification process a number of workshops will be held with DNV and project partners.
- [WP2E][WP3H][MP2][MP9] Co-ordination of modelling work and experimental works is taking place in parallel with the other (sub-)work packages.

Based on the above progress from year 1 it is expected that the project will be able to meet its original goals (or exceed them in some cases) and as such is expected to deliver useful results for industry and stakeholders.

3 Societal impact

Offshore wind energy is an essential technology in realising the objective as formulated in the Dutch *Klimaatakkoord* (Mission A): to realise a fully CO_2-emission free electricity system by 2050. To achieve this objective, it is essential to reduce costs and lower the impact on the ecology of offshore wind. It is therefore essential to develop new technologies for installing future XXL turbines, e.g. by developing innovative technologies to both install and decommission next generation turbines. The innovative technologies need to be cost-effective and ecologically friendly, which is of key importance for the Dutch-based wind industry to remain competitive. Strengthening the Dutch economy, by improved competitiveness, and reducing the energy production costs will both contribute to lower the economic costs ánd the societal costs of the energy supply in the Netherlands.

With current foundation installation technologies, the required XXL monopiles – the preferred foundation type for projects in the North Sea – cannot be installed without compromising constraints with respect to environmental impact, workability, and costs. SIMOX aims to accelerate the development and deployment of new technologies, by generating new and essential knowledge on the behaviour of these technologies and/or combinations thereof, under various test conditions. With SIMOX as an intermediate step, a larger contribution to realising the objective of Mission A can be realised, at lower costs, and at a higher pace. We expect that the innovative ecology-friendly installation techniques subject in this project will be commercially available around 2025, thus well before 2030.

SIMOX will address the MOOI-theme: Offshore wind energy, and in particular:

- *Optimal wind farm design*: SIMOX enables the development and deployment of large wind turbines, which can be installed on (XXL) monopiles by innovative technologies. Increasing turbine capacities still offers

significant potential for reductions in electricity generation costs. SIMOX will make installation of large monopile possible and can hence contribute to a continuous cost-reduction of offshore wind energy in the North Sea region.

- *Balance of plant optimisation*: SIMOX will accelerate the development of **low-cost** installation technologies for monopiles.
- *Integration in the offshore environment*: SIMOX will accelerate the development of **low-noise** installation technologies for monopiles. In addition, environmental and regulatory stakeholders will be involved in the process to ensure that environmental constraints are respected once the technology or technologies are applied.

SIMOX is an essential step in the development of innovative installation technologies, which are currently in an early stage of development. In SIMOX, we collect data, knowledge, insights and understanding of the behaviour of the subsurface to significantly improve these new technologies. Existing models will be improved to achieve the desired result. The focus is on testing (assessing performance), modelling and ultimately understanding the key physical behaviour of the monopiles under different circumstances, and their possible influence on the surroundings. SIMOX will, however, incorporate, where possible, the results of completed, ongoing and new research in this domain, which has a large involvement of the GROW Partners in the project consortium.

Although the focus of SIMOX is on installation, we will address the implications of design and installation on decommissioning as well. Particular installation practices may favour or inhibit decommissioning practices, or – more specific – decommissioning with minimal ecological impact. This include the impact on artificial reefs that may have originated around wind turbine foundations.

4 Knowledge dissemination and spin-offs

Within SIMOX, knowledge integration and dissemination will involve integration and dissemination activities of the knowledge acquired within the project. This not only concerns technical-economic knowledge, but also acquired knowledge and experience with the environmental and legal aspects concerning installation activities of (mono)piles. In this way, future legislation and regulations may serve the required products and services.

Within SIMOX the key actors in the global offshore wind energy market are represented, notably concerning the offshore contractors and project developers which will be the main end-users for the technologies in the scope of SIMOX. Through their direct participation in the project, the uptake of the SIMOX outcomes is ensured, provided that the outcome of the tests and modelling will support the expected advantages of one or more (combinations of) technologies. Non-industry stakeholders will participate in a stakeholder contact group and ensure that the outcome of SIMOX incorporates both environmental and economical opportunities. Within this SIMOX proposal the focus hence lies on internal project communication.

The following dissemination activities and public publications are available:

Project / Work Package		Year	Title/venue/authors/etc.
Generic	Publications	..	..
		..	..
	Workshops/conferences	1	BlueWeek Rotterdam – Blue Life & Ocean Energy Workshop - Installation with a nature-inclusive perspective – Dr. Ahmed Elkadi
		..	..
	Internet		www.grow-offshorewind.nl www.grow-simox.nl
WP1	Publications	..	..
		..	..
	Workshops/conferences	..	..
		..	..
WP2	Publications	..	..
		..	..
	Workshops/conferences	..	..
		..	..
WP3	Publications	..	..
		..	..
	Workshops/conferences	..	..
		..	..

References to SIMOX in media in reporting period:

Year 1

- https://www.offshorewind.biz/2022/05/31/orsted-ocean-winds-vattenfall-join-simox-project/
- https://www.grow-offshorewind.nl/newsitem/sustainable-and-low-cost-installation-of-monopile-foundations-for-future-very-large-wind-turbines
- https://www.offshorewind.biz/2021/02/02/research-project-on-sustainable-installation-of-xxl-monopiles-launched/
- https://windenergie-nieuws.nl/02/simox-en-robodock-offshore-wind-innovatieprojecten-ontvangen-subsidie-uit-mooi-regeling/
- https://w3.windfair.net/wind-energy/news/36702-sif-monopile-xxl-simox-consortium-technology-research-knowledge-wind-farm-offshore-large-hammering-fauna-grow
- https://windpowernl.com/2021/02/02/simox-robodock-receive-offshore-wind-innovation-subsidy/
- https://www.topsectorenergie.nl/en/nieuws/eu-73-million-subsidy-innovation-offshore-wind-projects
- https://www.4coffshore.com/news/ocean-winds2c-%C3%B8rsted-and-vattenfall-join-grow27s-monopile-project-nid25622.html
- https://gwec.net/wp-content/uploads/2022/06/GWEC-Global-Offshore-Wind-Report-2022.pdf p.32

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