Date 15-3-2024

Status Final

Dutch offshore Wind Farm Zones

Wake Study Offshore Wind 2030

Annex 5

SCOPE OF WORK

Colophon

Project name	Wake Study Offshore Wind 2030
Project number	
Version	Final
File name	SoW_Wakestudy2030_D
Project manager	Danielle Gerritsma
Contact	
Annex(es)	
Author	Danielle Gerritsma
Reviewed	Ufuk Kilinc, Andy Oldroyd, Matté Brijder
Approved	Huygen van Steen

Content

1 Introduction

1.1 Scope document

This document details the scope for a simulation study on wake effects on wind energy production in the Dutch North Sea.

1.2 Background

Offshore wind energy will play a large role in decarbonizing the Dutch energy supply. Due to the North Sea's advantageous wind climate and shallow water, offshore wind energy is relatively cheap and easily available. This resulted in large ambitious plans for offshore wind development, with the recently formulated joint ambition of several North Sea countries in Oostende to develop about 120 GW offshore wind on the North Sea by 2030, and 300 GW by 2050. Adding up the ambitions of other North Sea countries, the amount of future offshore wind will significantly increase.

However, large scale offshore wind development may come at a price; as more wind farms are added, the clustering effect of the wind farms has a distorting effect on meteorology. This results in lower yields, as wind energy is removed upwind from a respective wind farm. This impacts the energy yield potential of new wind farms, but also potentially the energy yield of existing wind farms.

The uncertainty in estimates of far wake effects is large, due to lack of measurements as a result of the unprecedented scale of development. Due to these uncertainties, it is hard to predict the effects of large scale clusters on energy yields. However, recent studies indicate that far wakes may be observed at 50 km distance[1] from a wind farm. As the first large wind farm clusters are developed in the North Sea (UK, the Netherlands, German Bight), measurements are increasingly available, allowing for validation of wake simulations.

1.3 Motivation

The Dutch roadmap aims to have 21 GW of offshore wind capacity installed around 2030, which is estimated to generate approximately 90 terawatt hours of electrical energy annually. It is important to better understand the relationship between installed capacity and the expected annual energy production. As permits for large wind farms are currently tendered, now is the moment to get insight into the effect of (far) wakes on energy yield, while taking into account recent developments in wake modelling with regards to temperature profiling and atmospheric stability, to fully understand wake losses at wind farm and cluster scale.

1.4 Objective of the study

Objective

The objective of this study is to gain an understanding of the influence of cluster (far) wakes on the energy yield of offshore wind farms in the Dutch part of the North Sea within the context of the additional offshore wind energy roadmap 2030[2] (referred to as Roadmap 2030).

Approach

To achieve this objective, we propose the execution of a comprehensive simulation study of the energy production of Dutch wind farms in the Roadmap 2030. This study will include operational and planned offshore wind farms, projecting forward to the year 2031. Multiple rollout scenarios leading up to 2031 will be explored to offer insights:

- regarding the potential impact range of cluster wakes on the energy yield;

[1] Schneemann, Rott, Dörenkämper, Steinfeld and Kühn (2020): Cluster wakes impact on a far-distant offshore wind farm's power

[2] https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/10/aanvullende-routekaart-windenergie-op-zee-2030

- for policy development through a more comprehensive determination of the expected energy yield after completion of the Roadmap 2030.

1.5 Planning and Deliverables

In this study, the abovementioned objectives are to be achieved using a mesoscale model focusing on the Dutch North Sea sector, including relevant surrounding areas. In this model, wind farm parametrisation is used to model all operational wind farms in this area, and future wind farms as defined in the Roadmap 2030. Using this model setup, different scenarios are run to identify the impact of turbine capacity or number.

This study is anticipated to consist of two phases. In the first phase, existing datasets are used for calibration and validation of the model. In the second phase, additional RVO measurements from a temperature profiler are used for validation of the model. As these measurements are still pending, this phase is optional.

The deliverables are detailed in chapter 2. The planning of these deliverables is to be decided and filled in by the Contractor, taking into account the provided dates in Table 1.

Table 1: overview of deliverables and planning

Action		**Deliverable**	**Date**
Start contract			**19-06-2024**
Phase I	Kick-off	Project plan document (including scenario description, aligned with RVO, including table of contents for the interim and final report)	
	Setup mesoscale model		
	Validate model with available data	Interim report with description model	
	Simulate scenarios	Results simulations in dashboard + data files underlying these results	
	Write report	Draft report	
	Incorporate feedback	Final report	31-01-2025
(Optional) Phase II	Validate model with new data	Interim report with validation model	
	Simulate scenarios	Results simulation in dashboard + datafiles underlying these results	
	Write report	Draft report	t.b.d. by RVO
	Incorporate feedback	Final report	

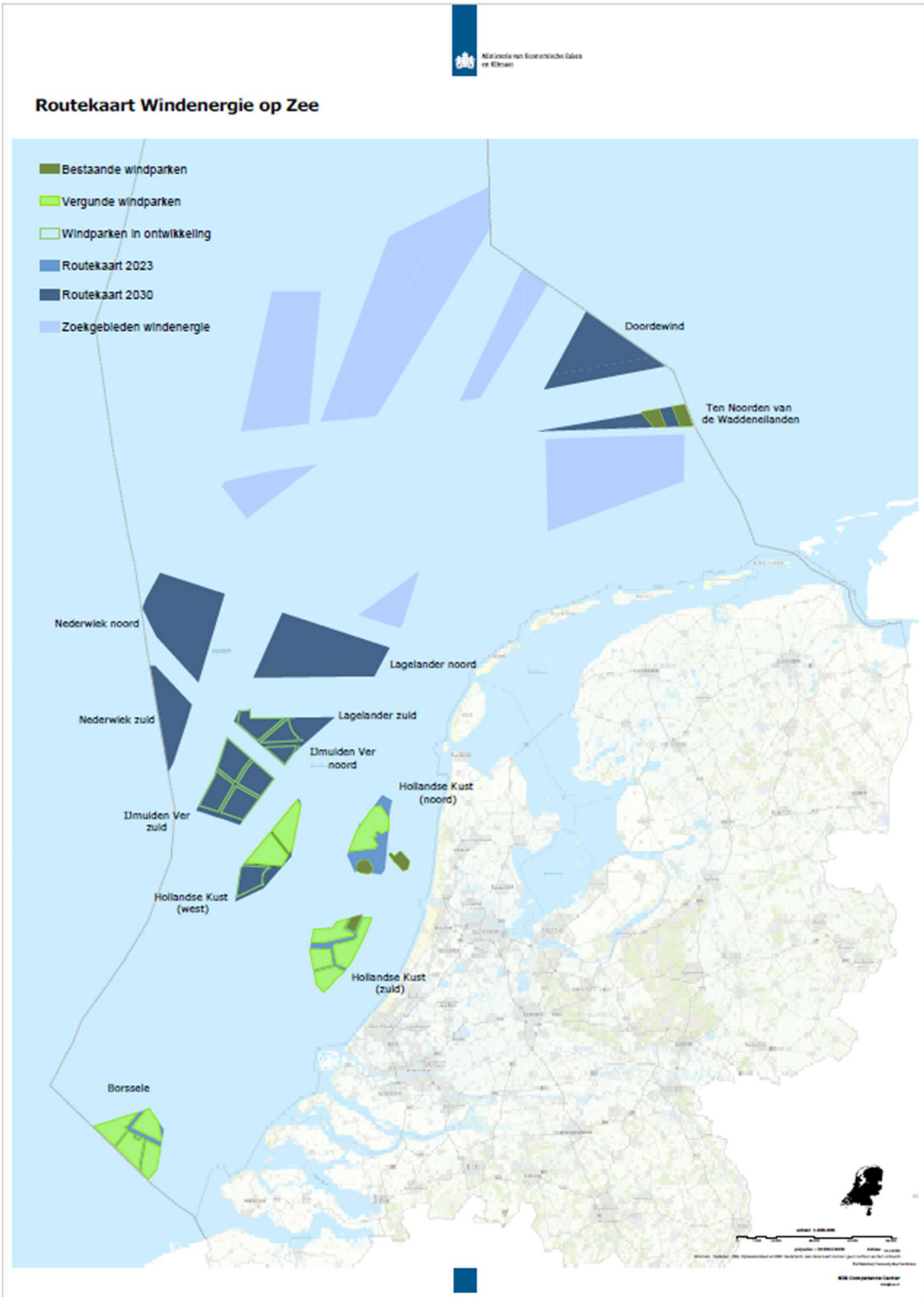

Figure 1: Map showing all operational, tendered and planned offshore wind farms in the Roadmap 2030 as well as offshore wind search areas in the Dutch North Sea.

1.6 **Interfaces with other studies**

For calibration and validation of the model, appropriate measurement data from the North Sea region should be used. These may include, but are not limited to datasets by TNO Uitrol van windenergie op zee (tno.nl) or RVO.

Preferably, floating Lidar measurement data is used from the wind farm sites as provided by RVO: https://offshorewind.rvo.nl/.

To identify waked measurements, the Contractor should use appropriate measurement datasets, such as the Doordewind 1 and Doordewind 2 datasets from RVO: Wind en Water Doordewind · Offshorewind RVO. These campaigns are still ongoing, and monthly datasets are provided on the website.

For the second phase, RVO will provide temperature profiler data, which includes temperature and pressure measurements on different heights. These are meant to validate model assumptions on atmospheric conditions. The timing and amount of data will be communicated by RVO during the first phase.

2 Scope of work

2.1 **Activity phase I**

2.1.1 Setup, calibration and validation model

This phase includes setting up the mesoscale model including wind farm parametrisation, based on the latest available information, such as results from X-wakes[3]. The domain extent, spatial resolution and nesting strategy should be defined by the contractor in the bid.

The selection of validation datasets should be appropriate for this exercise. Please note that available validation datasets may contain wake effected measurements. The identification of wake effected measurements should be described and compared to wake free signals and included in the report.

When the validations prove that the model performs well (meeting the KPI's set prior to the start of the project as part of the project plan, see 2.2), it can be used for simulating the different rollout scenarios for 2030.

Any variation to this approach should be documented in the tender stage.

2.1.2 Scenario runs

For wind farm parametrisation, characteristics of the wind farms should be known. For wind farms that have been tendered until 2023, turbine type, capacity and number specifics are known to some extent (see Table 2). Note that for Hollandse Kust West this is still under discussion; turbine type and capacity will be provided at the start of the Contract. Offshore wind farms Egmond aan Zee and Prinses Amalia may be decommissioned between now and 2031.

Table 2: overview of all tendered and/or operational wind farms, their distance from the coast, capacity, turbine types and capacity and owners.

Windfarm	Sites	Distance of the coast	Capacity	# Turbines	Turbine type
Offshore Wind Farm Egmond aan Zee (OWEZ)		10-18 km	108 MW	36	Vestas 3MW
Prinses Amalia Wind Farm		23 km	120 MW	60	Vestas 2 MW
Luchterduinen		23 km	129 MW	43	Vestas 3 MW
Gemini		85 km	600 MW	150	Siemens 4 MW
Borssele	I - II	22 km	752 MW	94	Siemens 8 MW
	III - IV		731,5 MW	77	Vestas 9,5 MW
	V		19 MW	2	Vestas 9,5 MW
Hollandse Kust (zuid)	I - IV	18 km	1529 MW	139	Siemens 11 MW
Hollandse Kust (noord)	V	18,5 km	759 MW	69	Siemens 11 MW
Hollandse Kust (west)	VI	53 km	≥700 MW	t.b.d.	t.b.d.
	VII		≥700 MW	t.b.d.	t.b.d.

However, for upcoming wind farm sites this is a challenge. These wind farm sites are listed in Table 3. As specifics are not available yet, this also introduces a large range of possibilities regarding wind farm lay-out and turbine types, capacities and numbers, each having its own impact in terms of wakes. The Tenderer is therefore asked to define and simulate different scenarios to explore the possibilities that

[3] X-Wakes (fraunhofer.de)

are most relevant to the purpose of the project. These scenarios and their methods and starting points should be described clearly in the provided Project Plan as part of this tender. The impact of different wind farms should be investigated, for example in by means of different time steps.

Table 3: overview of all future wind farms in the Roadmap 2030, the tender planning and their planned capacities.

Wind Farm Zones in the Dutch North Sea				
Wind Farm Zone	**Wind Farm Site**	**Tender**	**Capacity**	**Owner**
IJmuiden Ver	Alpha	Q1 2024	≥2 GW	t.b.d.
	Beta	Q1 2024	≥2 GW	t.b.d.
	Gamma	Q2 2025	≥2 GW	t.b.d.
Nederwiek	I	Q2 2025	≥2 GW	t.b.d.
	II	2026	≥2 GW	t.b.d.
	III	2026	≥2 GW	t.b.d.
Doordewind	I	2027	≥2 GW	t.b.d.

Although not all specifics for these wind farm sites are available, several boundary conditions can be assumed for all future wind farms in the Roadmap 2030:

- Each site is connected by a 2 GW grid connection
- A maximum of 15% overplanting is allowed
- A maximum rotor diameter of 280 m is allowed
- A maximum of 153 turbines is allowed
- A maximum total rotor surface area of 7081150 m^2 is allowed
- Lowest tip height of 25 m above mean sea level (MSL) is allowed
- Highest tip height of 304,8 m above MSL is allowed
- A minimum capacity of 15 MW per turbine
- A minimum distance of 4 rotor diameters between turbines

Offshore wind farm Ten noorden van de Waddeneilanden has been left out of the overview, as different boundary conditions apply to this wind farm. However, as these boundary conditions are still defined by the Ministry of Economic Affairs and Climate Policy – in consultation with the Ministry of the Interior and Kingdom relations, the Ministry of Infrastructure and Water Management and the Ministry of Agriculture, Nature and Food Quality-, these will be provided by the start of the Contract.

Shapefiles of the wind farm sites will be provided at the start of the Contract.

Other, external conditions should be defined based on the last available knowledge in the area of wake modelling and spatial planning. External conditions may include, but are not limited to, neighbouring country wind farms or climate change. Regarding neighbouring wind farm development, please take into account all expected developments towards 2031. The Contractor should identify the most relevant external conditions and perform a sensitivity study to estimate the impact on energy production.

2.1.3 Deliverables

- A project plan, including a table of contents for the interim and final reports, should be drafted quickly after the start of the contract. During the kick-off, potential issues are tackled which are to be included in this project plan. In this project plan, the KPI's are also defined by the Contractor to which the model validation should be held.
- Interim report describing the model setup and performance, including input parameters, assumptions and model uncertainties.
- The interim report should include the wind climate at each Dutch Sector wind farm and expected energy yield for each timestep modelled. The absolute energy output and expected change in output as predicted by the model against the baseline case should be clearly presented.
- A GIS-based dashboard (or other visual (online) representation) showing the results, where the user can switch between the different scenarios. The impact of turbine capacity and turbine number should be clearly visible.
- Data files underlying the visual represented results on hard drive
- A final report describing the underlying assumptions and shortcomings of the exercise, with recommendations for the use of the results (including clear description of the uncertainties).

Contractor shall allow for sufficient time for review and revision taking into account the review periods by Contracting authority within 15 working days for the first revision and 5 working days for each revision thereafter. It is up to Contractor to organize review and submission of deliverables in the most efficient way allowing for mentioned review periods and of period of 20 working days for certification and fulfilling the defined submission dates for first draft and certificate final deliverables.

2.2 **Optional scope item: Activity phase II**

2.2.1 Validation and scenario runs

After the temperature profiler data is available (preferably 12 months, but at a minimum 6 months), the model is validated again using the new data. Based on the results, the contractor has to decide how to incorporate this new data (e.g. full correction by rerun, or bias correction). After validation, the scenario runs as described under 2.1.2 should be repeated.

2.2.2 Deliverables

- Interim report describing the model setup and performance, including input parameters, assumptions and model uncertainties
- A GIS-based dashboard (or other (online) visualisation of the results) showing the results, where the user can switch between the different scenarios. The impact of turbine capacity and turbine number should be clearly visible.
- Data files underlying the visual represented results on hard drive.
- A final report describing the underlying assumptions and shortcomings of the exercise, with recommendations for the use of the results (including clear description of the uncertainties).