



Netherlands Enterprise Agency

Webinar Combined Wind Resource Assessment for Hollandse Kust (zuid) WFZ

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Welcome

- > Introduction speaker and panel
- > Goal of this webinar
- > Agenda





Have a successful meeting!





HOLLANDSE KUST (ZUID) COMBINED WIND RESOURCE ASSESSMENT

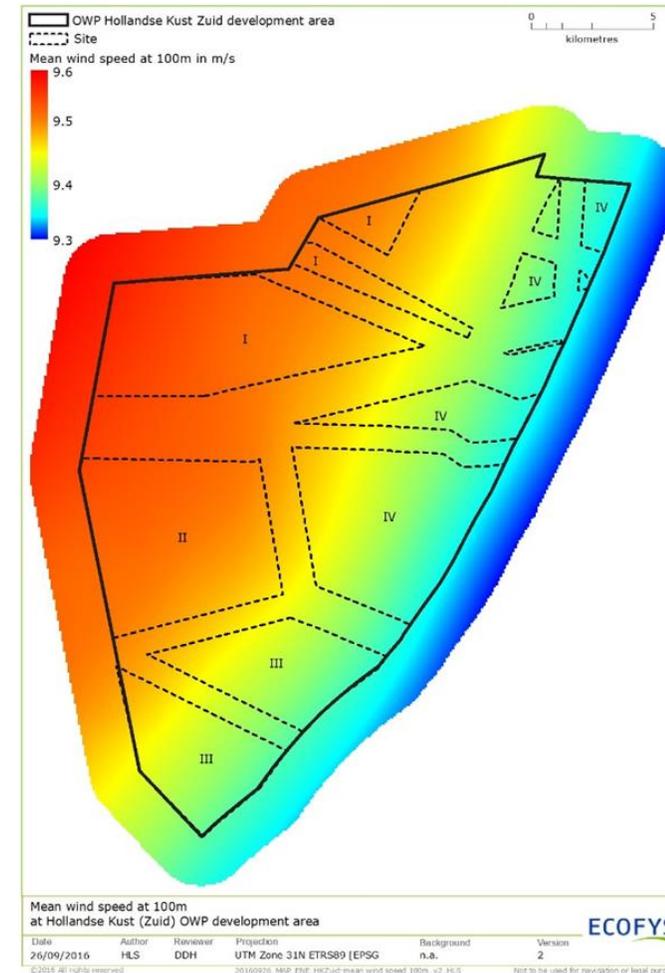
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OVERVIEW

Chapters:

| | |
|-------------|----------------------------------|
| Slide 3-4 | Introduction |
| Slide 5-6 | Wind measurements and approach |
| Slide 7-9 | Summary: 1st WRA |
| Slide 10-12 | 2nd WRA: additional measurements |
| Slide 13-14 | Calculation of wind climate |
| Slide 15 | Comparisons |
| Slide 16-18 | Conclusions |



INTRODUCTION

Ecofys WTTS

Ecofys WTTS provides high quality wind measurement services, wind resource & yield prediction assessments and operates remote sensing devices on behalf of its clients, based on its 15-year experience.

Since its foundation in 2010, Ecofys WTTS is also the operator of the largest site for wind turbine prototyping testing and certification in Europe, located in Lelystad in the Netherlands.

Ecofys WTTS is a subsidiary of Ecofys, a consultancy company with an international track record of 30 years in the wind energy sector.

Navigant

Ecofys has recently (November 7, 2016) been acquired by Navigant Consulting, Inc. (NYSE: NCI); , a specialized, global professional services firm, with a leading Energy Practice. The firm is headquartered in Chicago, United States, with more than 5,000 employees worldwide.

INTRODUCTION

Goals of the study

- RVO.nl commissioned two preliminary independent wind resource assessment for the Hollandse Kust (zuid) Wind Farm Zone and its four sites
 - WRA1 (published Dec 2016) – based on off-site wind measurements, with long-term correction and horizontal extrapolation to site
 - WRA2 (presented here) – based on on-site wind measurements, with long-term correction
- The scope of the combined study is defined by RVO.nl:

This Ecofys WTTS study describes the mean wind climate at 100 m. Mean wind speeds are also calculated at other heights. This information is intended for wind farm modelling, yield assessments and business case calculations for offshore wind farms to be developed in the Hollandse Kust (zuid) wind farm area.

WIND MEASUREMENTS & APPROACH

Primary wind measurements

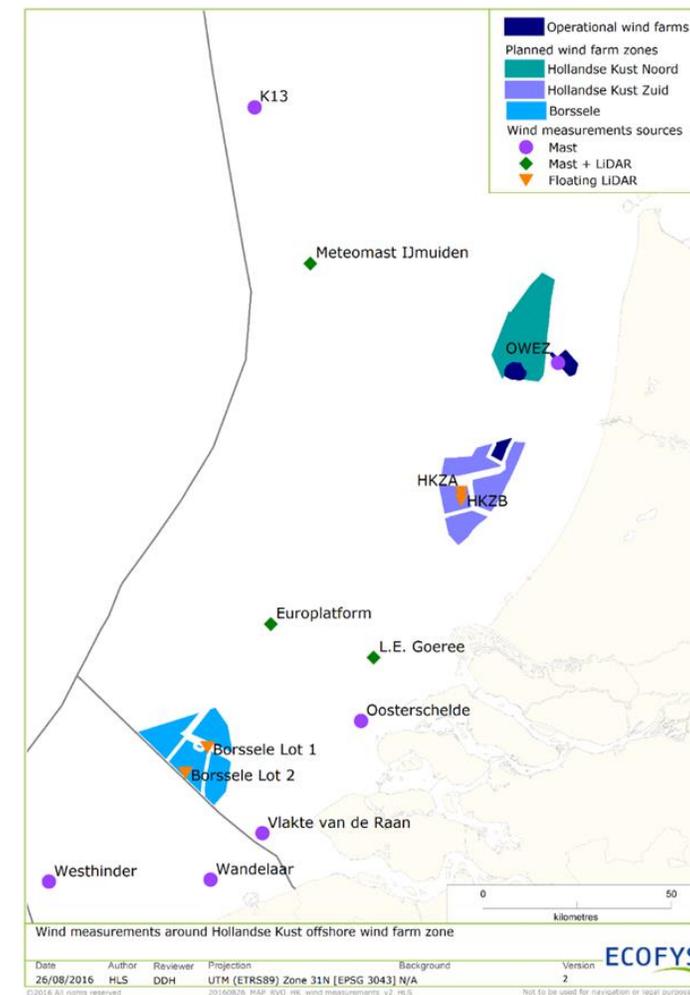
- 116 m OWEZ met mast (WRA1)
- HKZA & HKZB floating LiDARs (WRA2)

Secondary met masts

- 92 m Meteomast IJmuiden
- 29 m Europlatform
- 38 m Lichteiland Goeree

Secondary LiDARs

- Borssele Lot-1 floating LiDAR
- Meteomast IJmuiden
- Europlatform
- Lichteiland Goeree



WIND MEASUREMENTS & APPROACH

Methodology (for both WRA studies)

1. Selection of highest-quality primary wind measurements
2. Selection and validation of secondary data sources for long-term correction and horizontal extrapolation
3. Calculation of on-site wind climate
 - a) Vertical extrapolation
 - b) Long-term correction
 - c) Horizontal extrapolation
4. Comparison to other site studies
5. Validation of key results and trends

SUMMARY: WRA1 WIND MEASUREMENTS

| | OWEZ |
|--|--|
| Measurement type | 116 m offshore mast |
| Location [Latitude, longitude: ETRS89] | 52°36'22.89" N / 4°23'22.68" E |
| Distance from coast | 15 km |
| Measurement period | 07/2005 - 06/2006 (1.0 year) |
| Measurement interval | 10-minute |
| Documentation | Mast design and data manual [6] Data filtering manual [7] |
| Traceable instruments | MEASNET calibrated anemometers; other instruments also calibrated; regular maintenance by Mierij Meteo |
| Availability of valid data | 85.7% at 116 m and 95.7% at 70 m |



Source: Noordzeewind

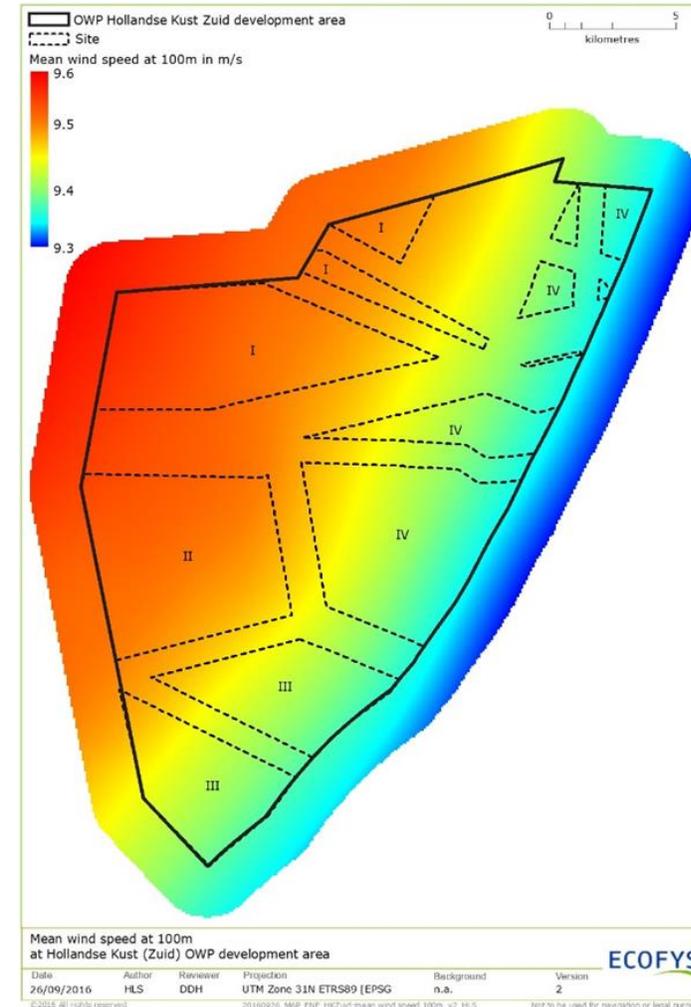
SUMMARY: WRA1 CALCULATED CLIMATE

- Primary source: 1 year of OWEZ wind measurements at 70 m
 1. Extrapolation from measurement height to 100 m, based on average measured shear profile
 2. Long-term correction and extension from 1 years of measurements to a 16-year period (2000-2016), based on MCP with EMD-ConWx model data
 3. Extrapolation from the measurement location to the Hollandse Kust (zuid) zone, based on horizontal gradient in EMD-ConWx model data

SUMMARY: WRA1 CALCULATED CLIMATE

9.46 ± 0.47 m/s at 100 m
at zone centre

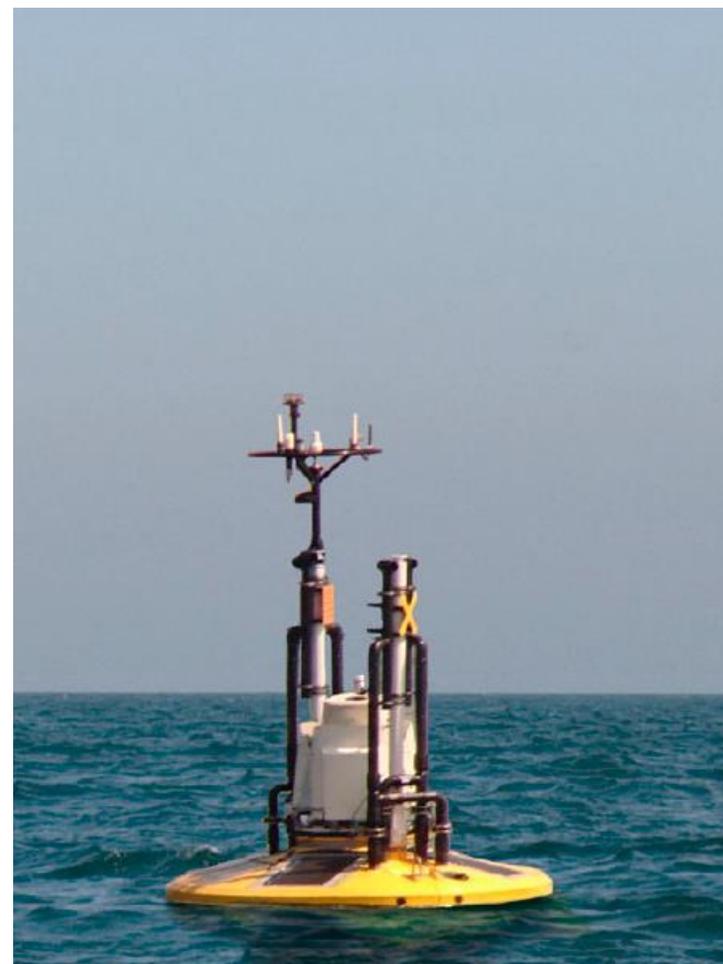
| Uncertainty description | HKZ |
|--------------------------------|-------------|
| - Instrument accuracy | 2.0% |
| - Instrument mounting | 2.5% |
| - Data quality | 0.5% |
| - Data processing | 1.0% |
| - Vertical extrapolation | 0.3% |
| - Horizontal extrapolation | 1.0% |
| - Long term representation | 1.5% |
| - MCP | 0.7% |
| - Mesoscale model distribution | 3.1% |
| Total | 5.0% |



WRA2 PRIMARY WIND MEASUREMENTS

| | HKZB |
|--|--|
| Measurement type | ZephIR 300S LiDAR |
| Measurement heights | 30, 40, 60, 80, 100, 120, 140, 160, 180, 200 m MSL |
| Location [UTM ETRS89 Zone 31] buoy WS158 | 568,792 m E / 5,793,671 m N |
| Distance from coast | 26 km |
| Distance from zone centre | 4 km |
| Measurement period | 05/06/2016 – 05/06/2017 (1 year) |
| Measurement interval | 10-minute |
| Documentation | Setup, data manual and monthly data reports [13] [27] [28] |
| Traceable instruments | Type-specific verification report, and Ecofys WTTS uncertainty assessment [10] [11] and pre-deployment validation of unit [14] |
| Availability of valid data | 95.0% |

- With gap-filling with HKZA, availability = 98%



Source: Deltares

WRA2 SECONDARY WIND MEASUREMENTS

| | Lichteiland Goeree mast |
|---------------------------------------|--|
| Measurement type | Offshore mast |
| Measurement heights | 38.3 m |
| Location [UTM ETRS89 Zone 31] | 545,876 m E / 5,752,029 m N |
| Distance from coast | 17 km |
| Distance from zone centre | 52 km |
| Measurement period | 01/04/2003 – 01/07/2017 (14.3 years) |
| Measurement interval | 10-minute |
| Documentation | General description, 2001 [1] Mast drawings [4] |
| Traceable instruments | No details of calibration or maintenance |
| Availability of valid wind speed data | 98.4% |

- Co-located LiDAR (during 2.6 years), used to extrapolate measurements to 100 m

| | Lichteiland Goeree LiDAR |
|---------------------------------------|---|
| Measurement type | Windcube V2 LiDAR |
| Measurement heights | 62, 90, 115, 140, 165, 190, 215, 240, 265, 290 m MSL |
| Location [UTM ETRS89 Zone 31] | 545,876 m E / 5,752,029 m N |
| Distance from coast | 17 km |
| Distance from zone centre | 52 km |
| Measurement period | 17/11/2014 – 13/06/2017 (2.6 years) |
| Measurement interval | 10-minute |
| Documentation | None |
| Traceable instruments | Validation report [5] |
| Availability of valid wind speed data | 74% at 62, 90, 115 & 140 m; decreasing to 32% at 290 m |



Source: Vem Bouwkundig en Civieltechnisch Adviesbureau



Source: NAPNAM Publishing & Consulting

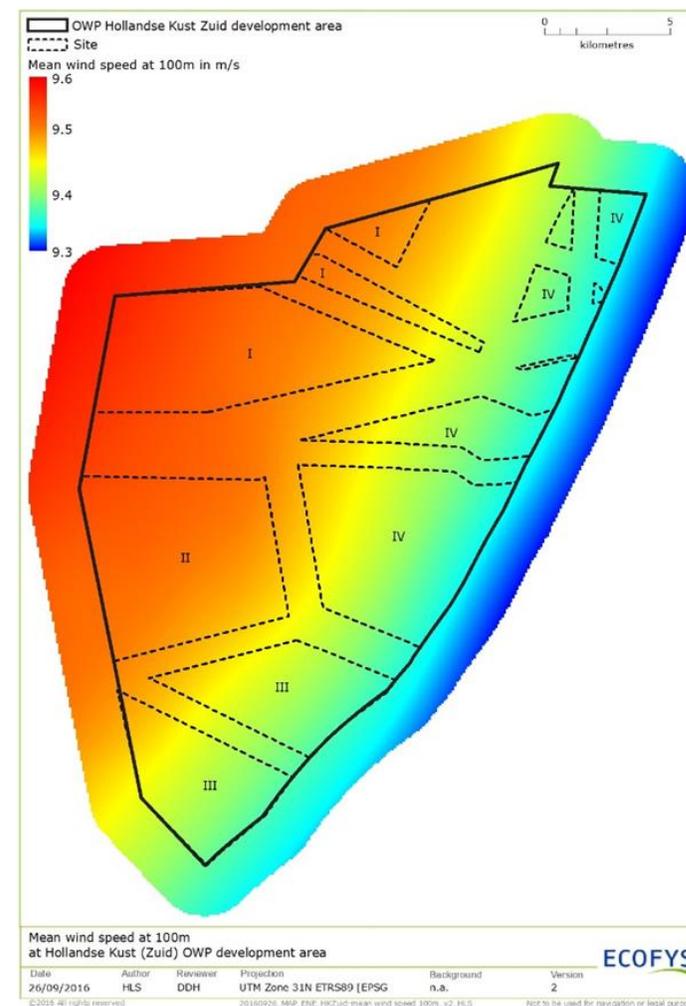
WRA2 CALCULATED CLIMATE

- Primary source: 1 year of HKZB wind measurements at 100 m, with gap-filling with HKZA (co-located)
 1. No vertical extrapolation needed
 2. Long-term correction and extension from 1 years of measurements to a 14-year period (2003-2017), based on MCP with LE Goeree mast/LiDAR data
 3. Extrapolation from the measurement location at centre of Hollandse Kust (zuid) zone to the four sites, based on horizontal gradient in EMD-ConWx model data

WRA2 CALCULATED CLIMATE

9.41 ± 0.52 m/s at 100 m
at zone centre

| Uncertainty description | HKZB + LE Goeree |
|----------------------------|---------------------|
| - Instrument accuracy | 3.3% |
| - Instrument mounting | 0.5% |
| - Data quality | 1.0% |
| - Data processing | 2.0% |
| - Vertical extrapolation | 0% |
| - Horizontal extrapolation | 0.5% |
| - Long term representation | 1.6% |
| - Long-term correction | 3.4% |
| Total | 5.6% |



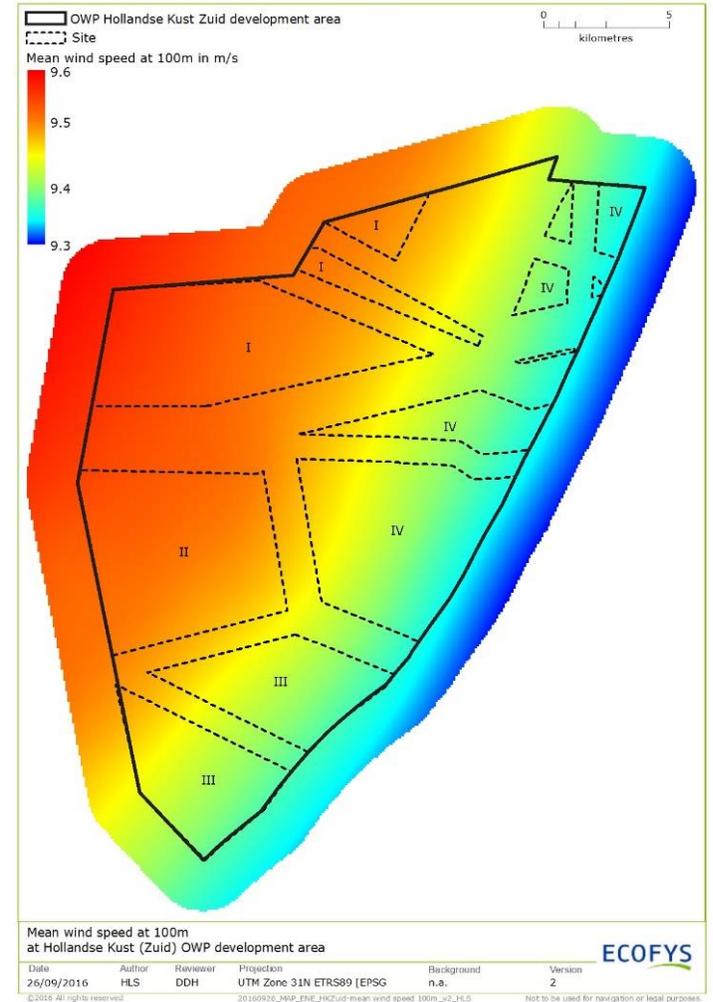
WRA1 + WRA2 COMBINED CLIMATE

- Results of WRA1 and WRA2 are highly consistent
- Both calculations are largely independent
- Thus, it is possible to combine, using inverse-variance weighting method

Weighting: **55% WRA1, 45% WRA2**

Combined uncertainty: **4.0%**

9.44 ± 0.38 m/s at 100 m at zone centre

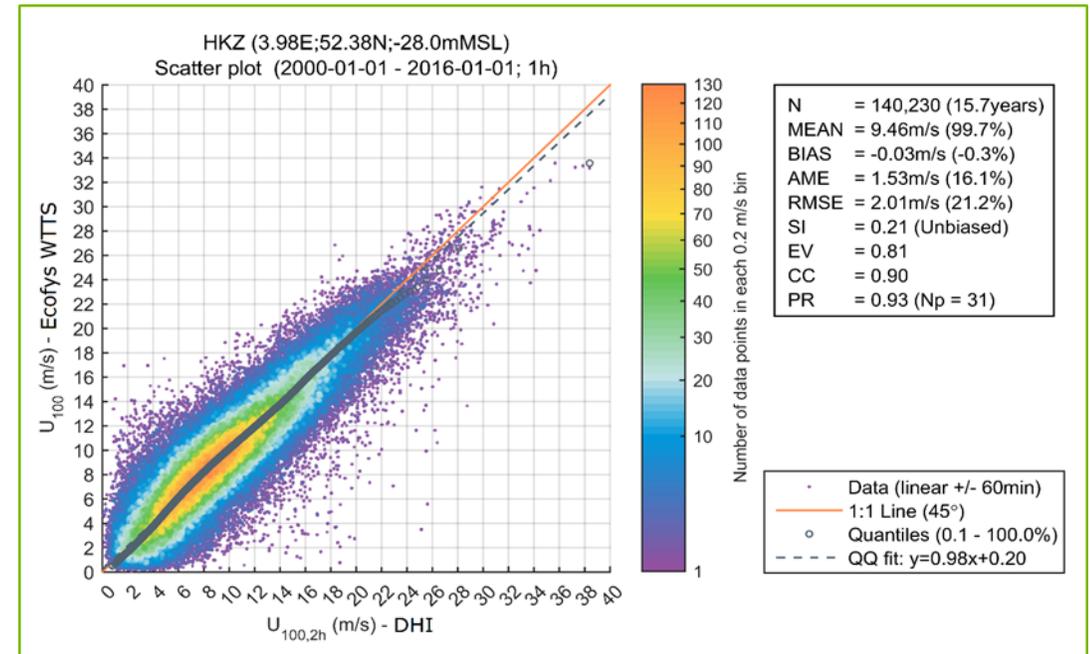


COMPARISON

- RVO.nl has also commissioned DHI to perform metocean desk study for the Hollandse Kust (zuid) offshore wind farm zone, with a different scope:

The DHI report and metocean database describe the normal and extreme wind conditions. This includes turbulence intensity, extreme wind speeds and wind shear. This information is intended for wind farm design

- Both reports found a **mean wind speed at 100 m of 9.5 m/s**, with excellent correlation between the time series and similar trends. The use of results from both studies is dictated by the separate scope of the two reports



VALIDATION OF KEY RESULTS

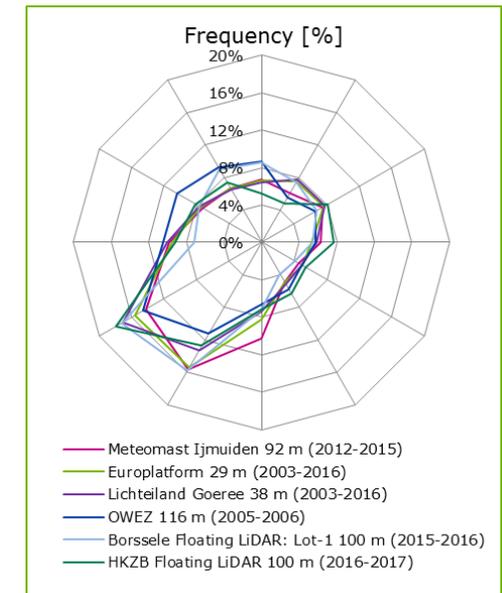
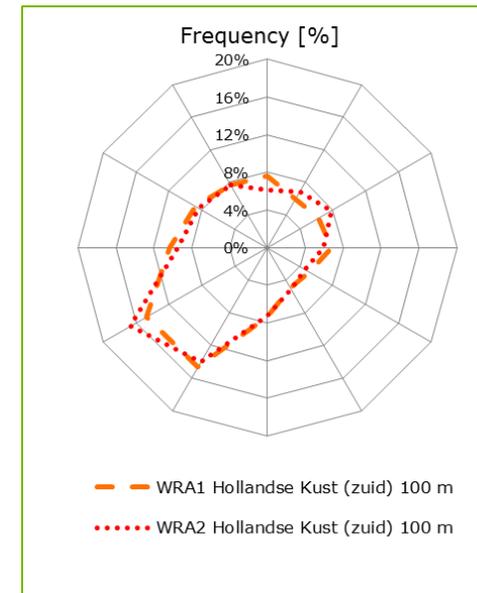
- Detailed analyses of the calculated wind climate were carried out across the modelled heights, showing good comparisons of the analysed trends with measurements at other offshore sites in the Dutch North Sea

- Mean wind speed
- Wind shear
- Diurnal variation
- Monthly variation

- Inter-annual variation
- Frequency distribution
- Weibull parameters
- Wind rose

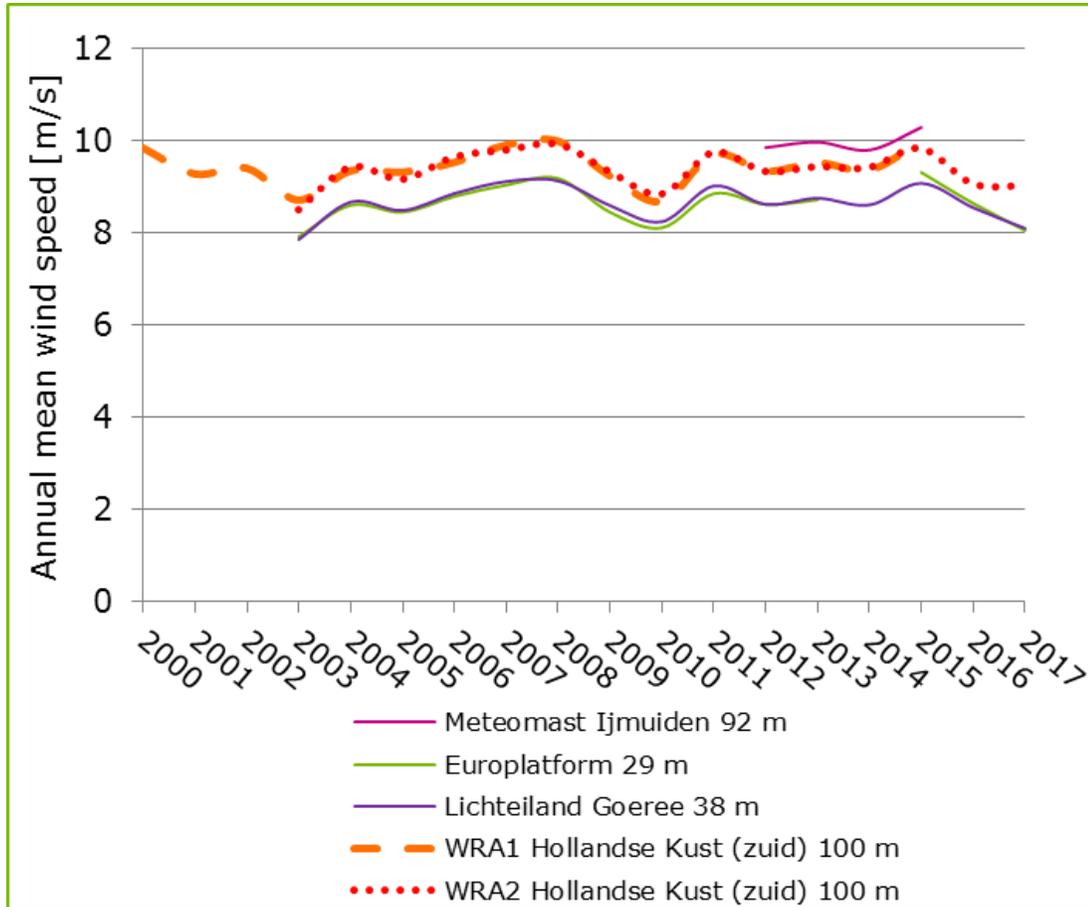
- Temp., pres., humid.
- Air density
- Wake effects

- See report for details



VALIDATION OF KEY RESULTS

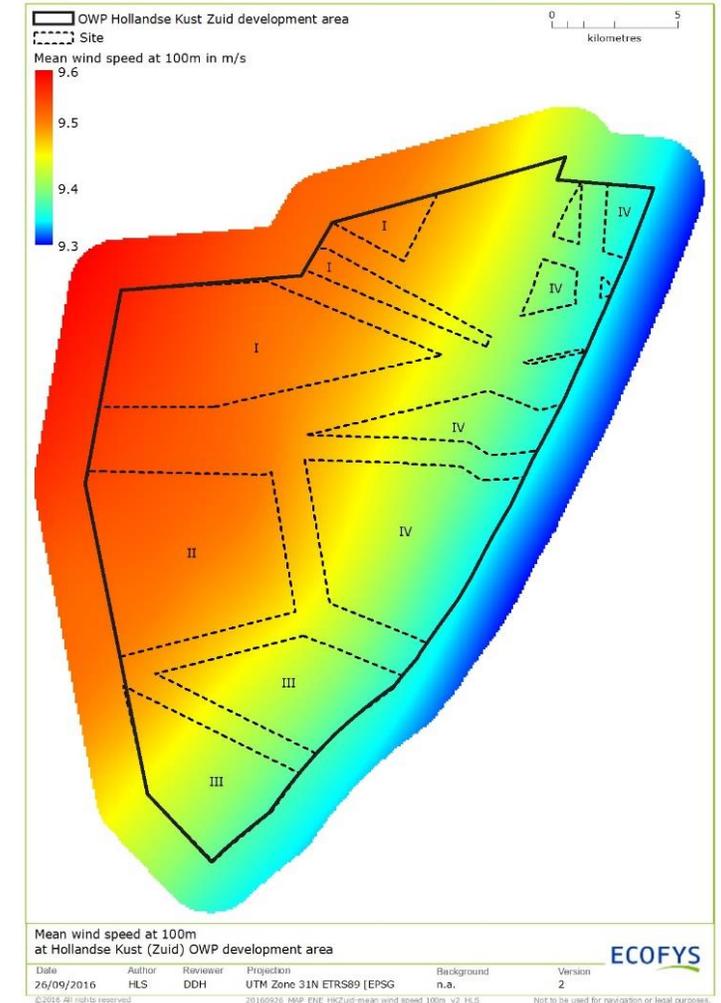
- Annual wind speed variation plot showing good comparisons of the analysed trends



WRA1 + WRA2 COMBINED CLIMATE

9.44 ± 0.38 m/s at 100 m at zone centre

- Report published online
 - Extensively reviewed by RVO.nl, BLIX, ECN, Fichtner & DHI
 - Certified by DNV GL
- Other deliverables available online
 - Calculated wind speed & direction time series at zone centre & 4 site centres
 - GIS layer





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Closing

- › Questionnaire
- › Lessons learned
- › Availability panel
- › Communications
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 - woz@rvo.nl





Thank you very much!

