Wind EUROPE OFFSHORE 2019
26-28 NOVEMBER COPENHAGEN

windPRO

# Temporal Wake Modelling
## Validation with iSpin Measurement

**Henrik S. Pedersen (1), Wiebke Langreder (1), Adit N. Kishore (1), Harald Hohlen (2)**
(1) EMD International A/S, (2) ROMO Wind A/S

ROMO WIND

EMD International

# Temporal Wake Modelling

Agenda:

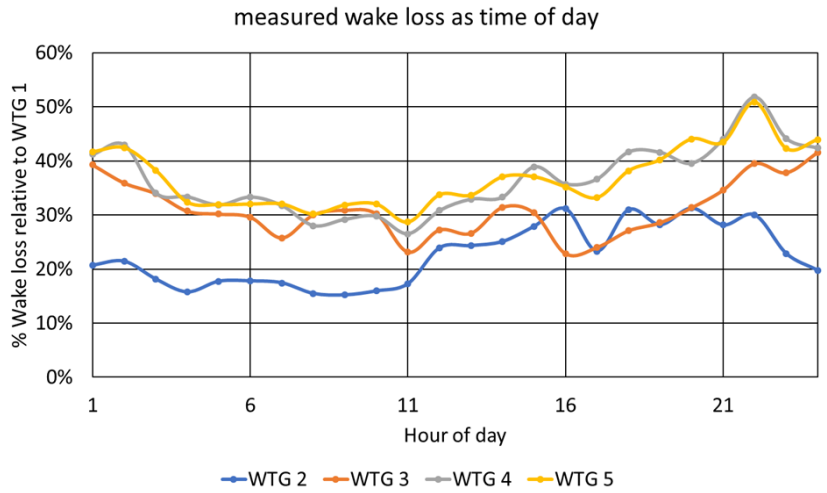
1. Problem
    I. Wake losses and their time dependency
2. Methodology
    I. The site
    II. 10-minute time-varying park calculation
    III. Comparison between measured and modelled wind and production
3. Failure!!!
    I. Moving time frame
4. Results

EMD International

# Motivation

Hypothesis:

We can use turbulence intensity (TI) as a proxy for stability in a given time-step, using a time-varying park calculation to more accurately estimate the Wake Decay Constant (WDC) and consequently the wake loss.



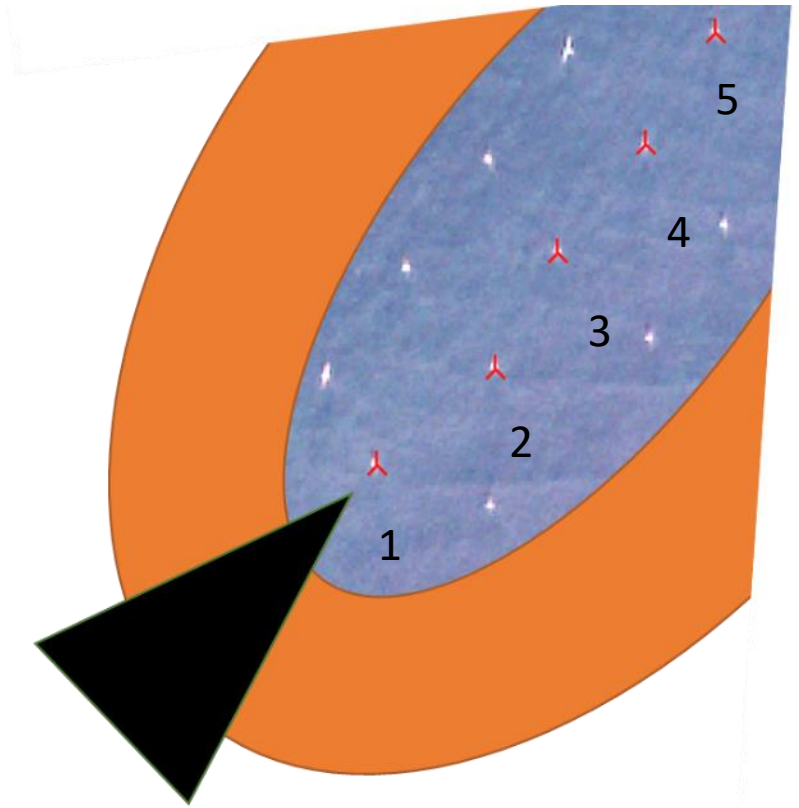

- Unstable conditions – High TI - High WDC -> Low Wake Losses
- Stable conditions - Low TI – Low WDC -> High Wake Losses

The impact of turbulence intensity and atmospheric stability on power deficits due to wind turbine wakes at Horns Rev wind farm: Hansen, Kurt Schaldemose
DOI: 10.1002/we.512

EMD International

# Methodology

- Large offshore wind farm: +70 WTGs
- Five turbines equipped with iSpin measurement system: one year of 10-minute wind speed and direction, turbulence intensity
- 10-minute SCADA data provided from these 5 turbines
- windPRO time-varying park calculation, using measured wind conditions from WTG1 as input for time-varying calculation




EMD International

# iSpin System

ROMO WIND
WIND KNOWLEDGE IS WIND POWER

iSpin system correctly measures*:

- Wind speed
- Wind direction
- Turbulence intensity (TI)

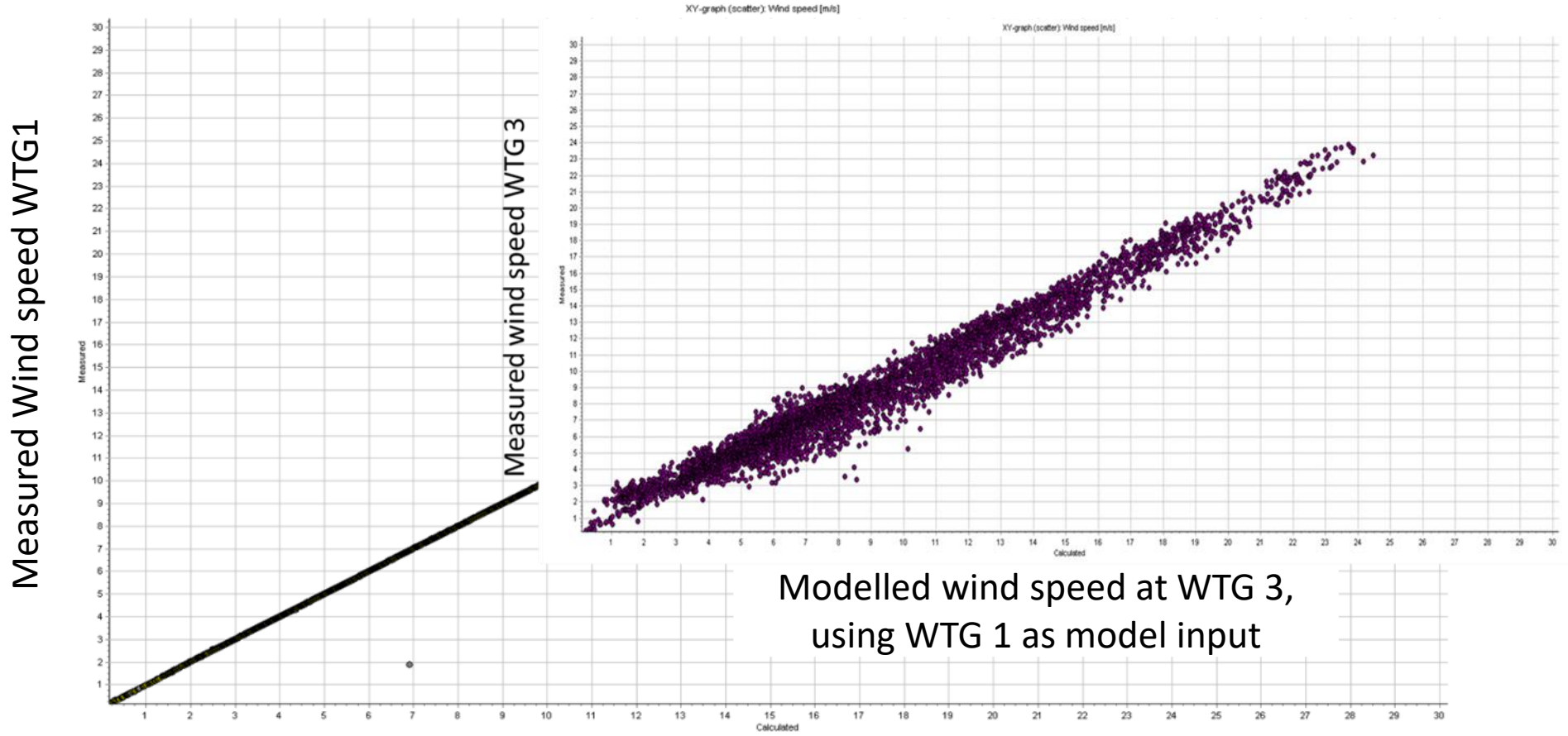
Consequently the velocity deficit inside the wind farm has been measured as well as TI

See also: PO.128: Long-term Comparison of Spinner Anemometer and Nacelle Lidar Data for an Offshore Wind Farm

*DNV.GL: Review of the Spinner anemometer from ROMO Wind iSpin. 113605-DKAR-R-01, Rev.3: 2015

EMD International

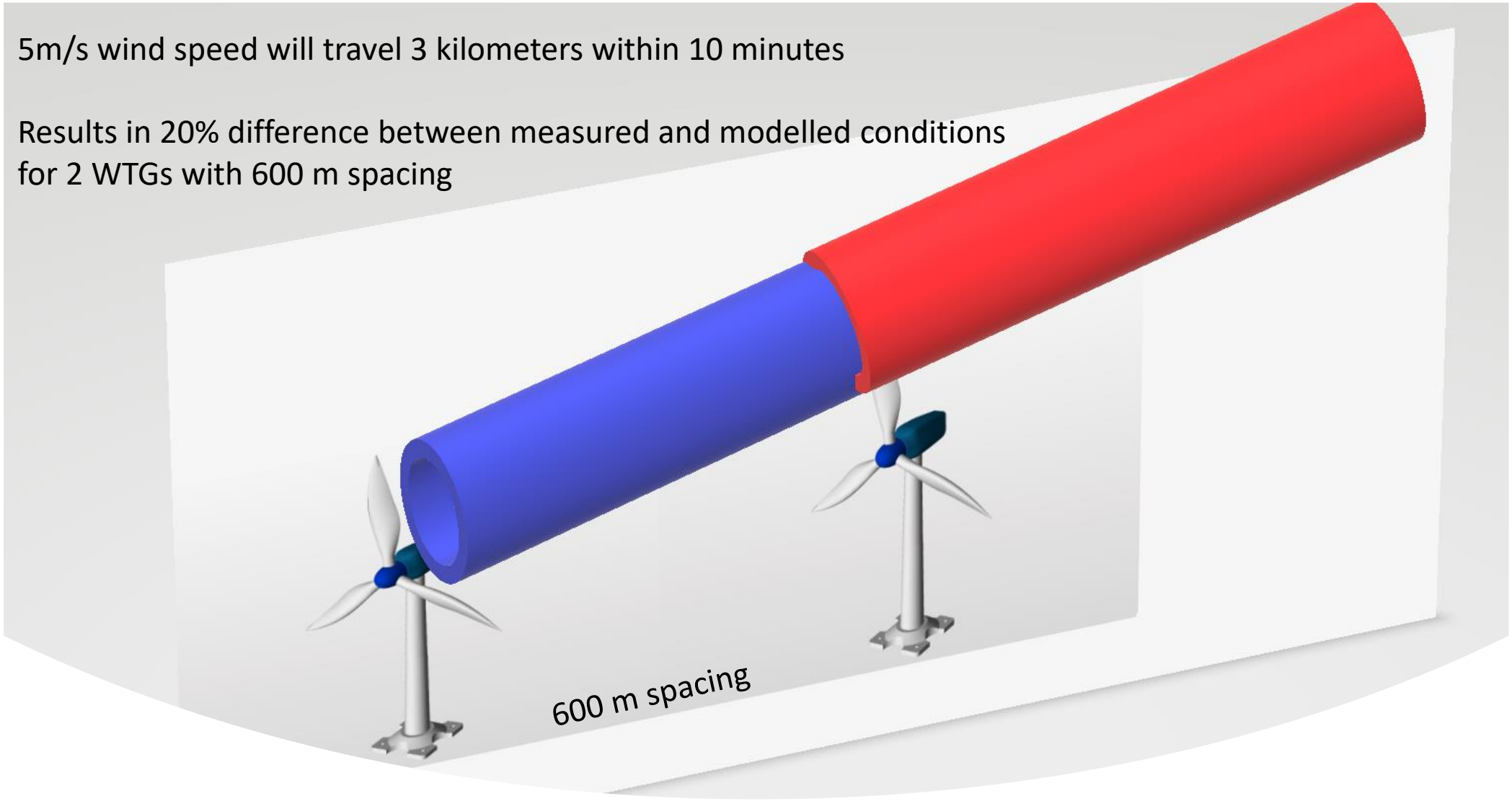
# Problem!!!  Moving Time Frame



# Moving Time Frame

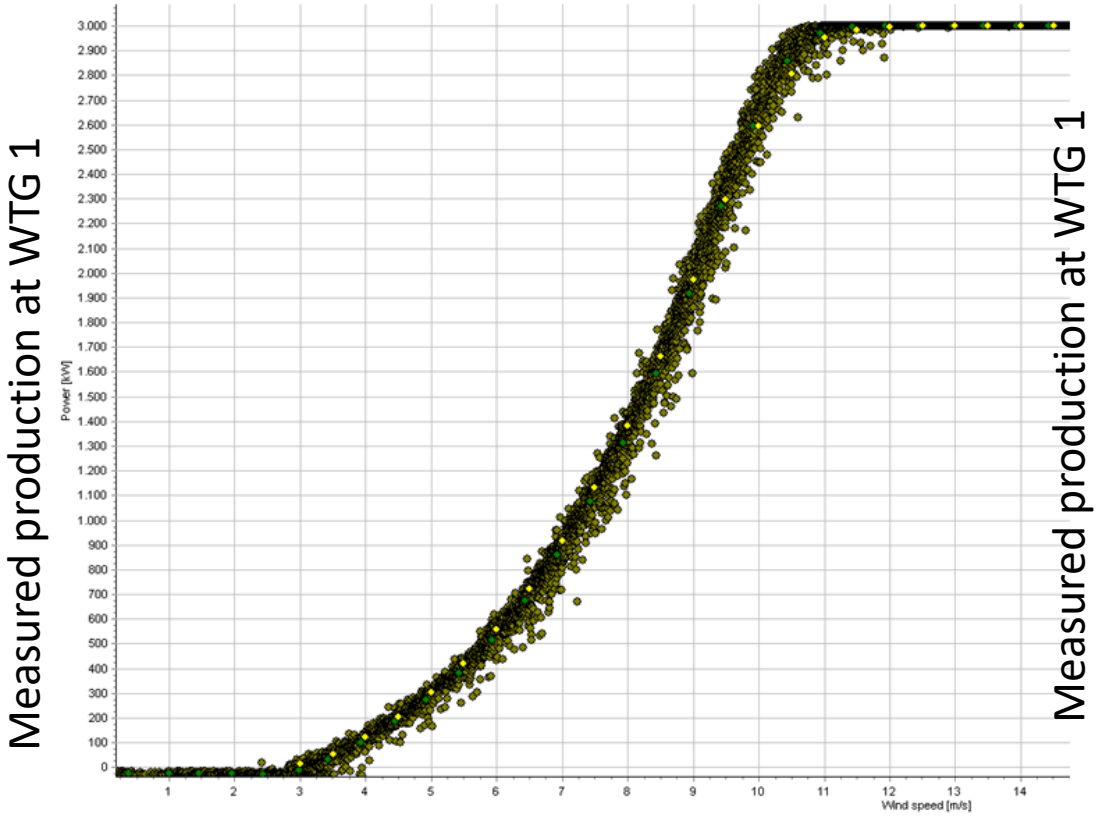
5m/s wind speed will travel 3 kilometers within 10 minutes

Results in 20% difference between measured and modelled conditions for 2 WTGs with 600 m spacing

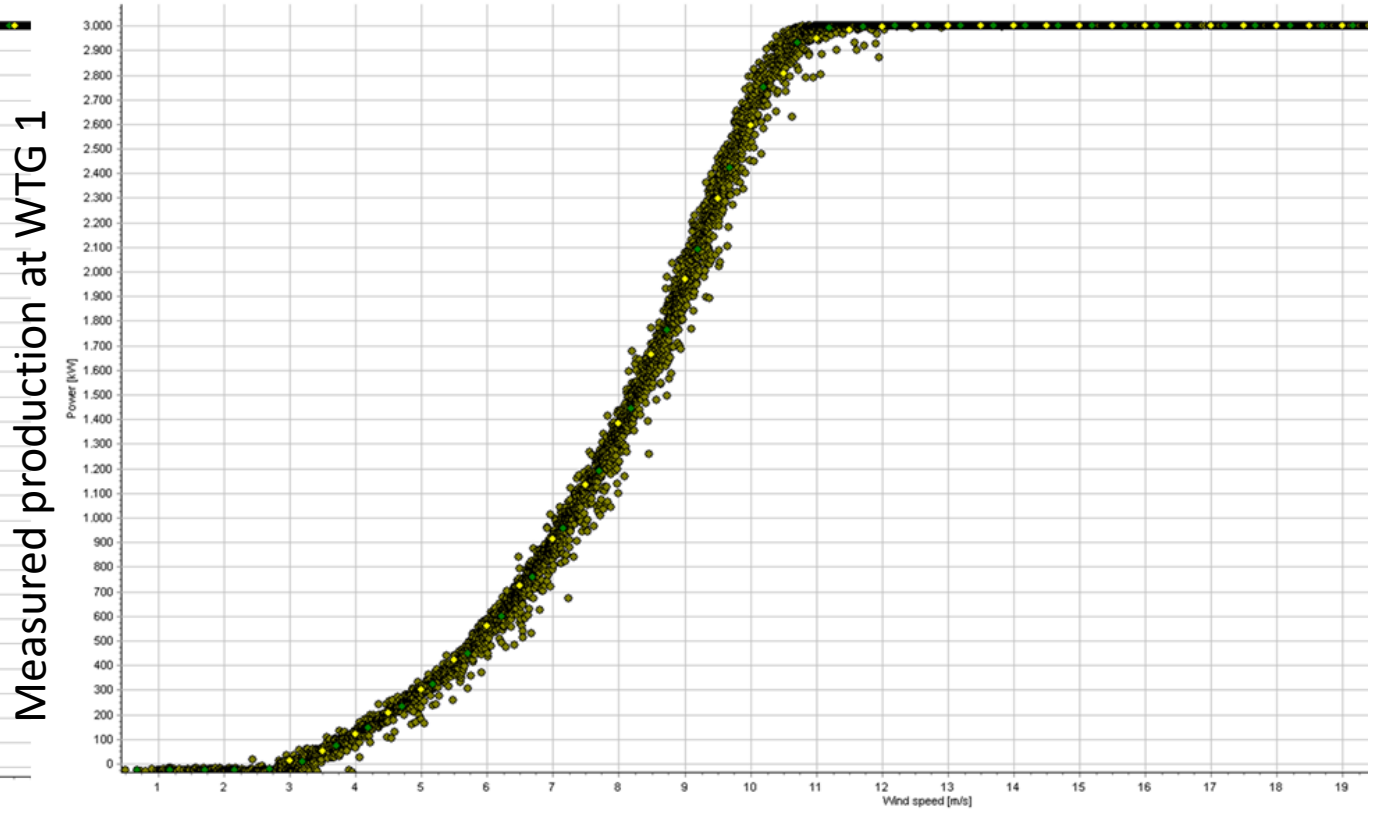



EMD International

# Moving Time Frame




iSpin measured wind speed



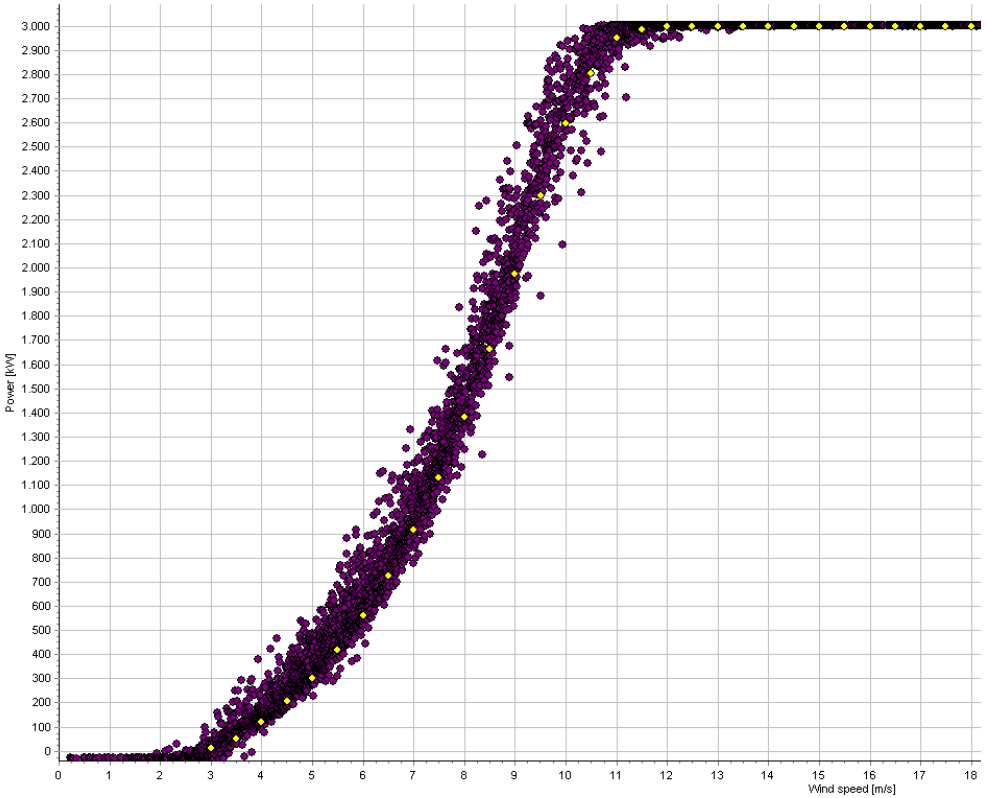

Modelled wind speed

EMD International

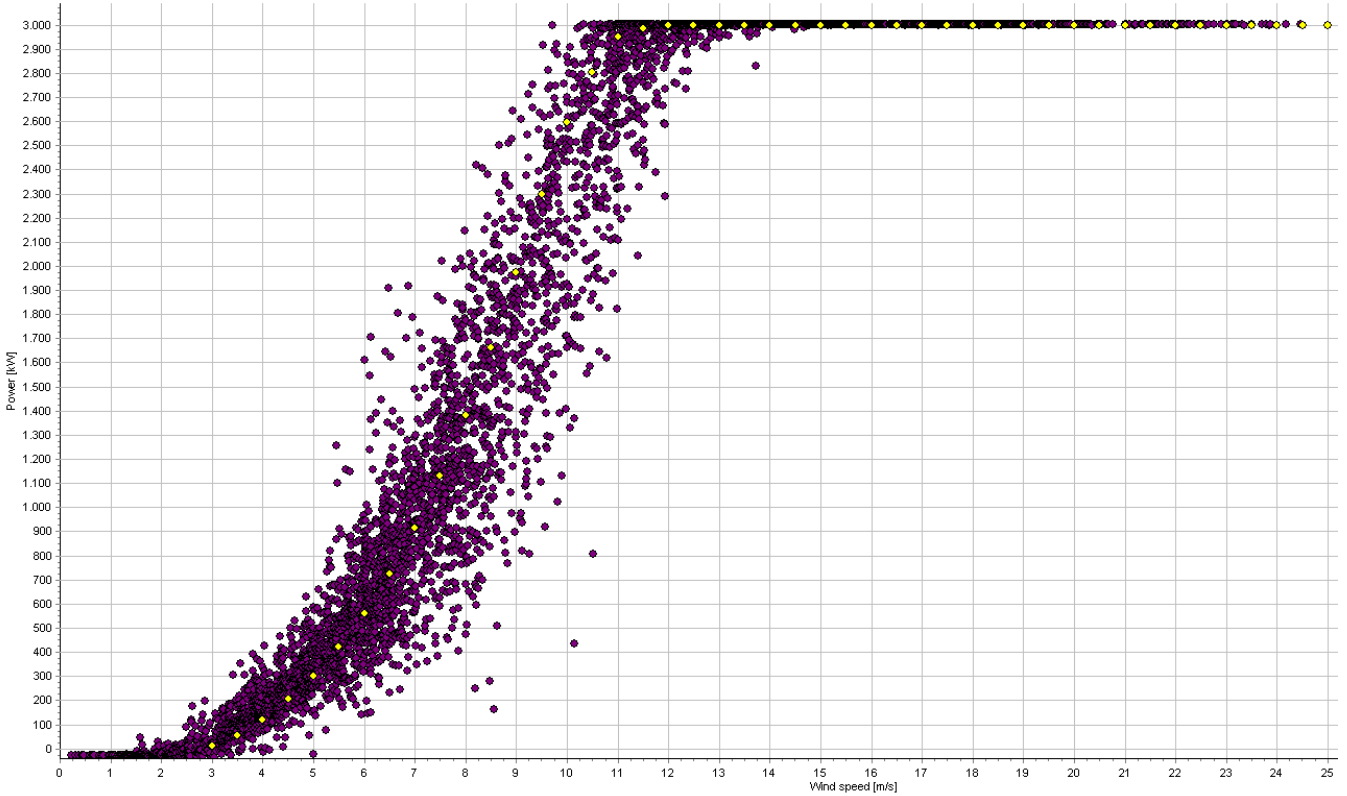
# Moving Time Frame

10-minute wind speed at position of WTG 1 is NOT comparable to a concurrent time period at a different location

Measured production at WTG 3




iSpin Measured wind speed



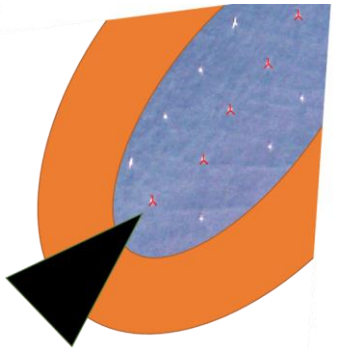

Modelled wind speed at WTG 3, using WTG 1 as model input

EMD International

# Results

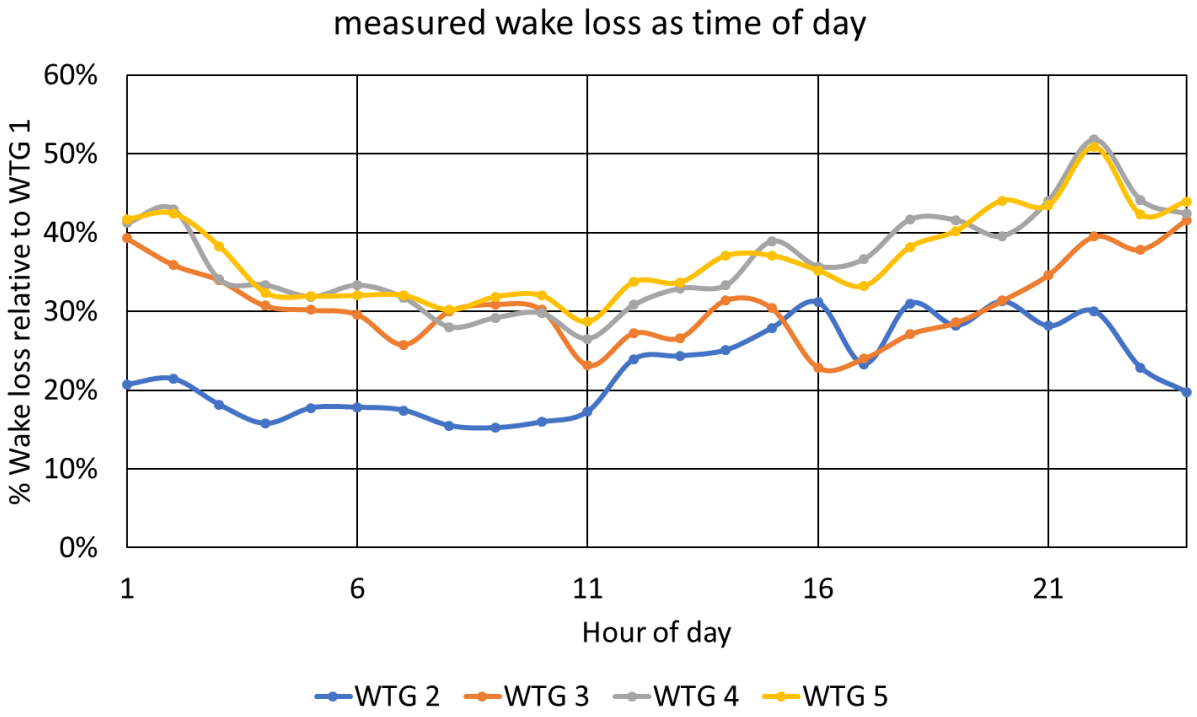
- Not possible to compare 10-minute measurements to 10-minute modelled values as the real data is still affected by:
  - Time shift
  - Wind direction changes
  - Stability
  - Etc.

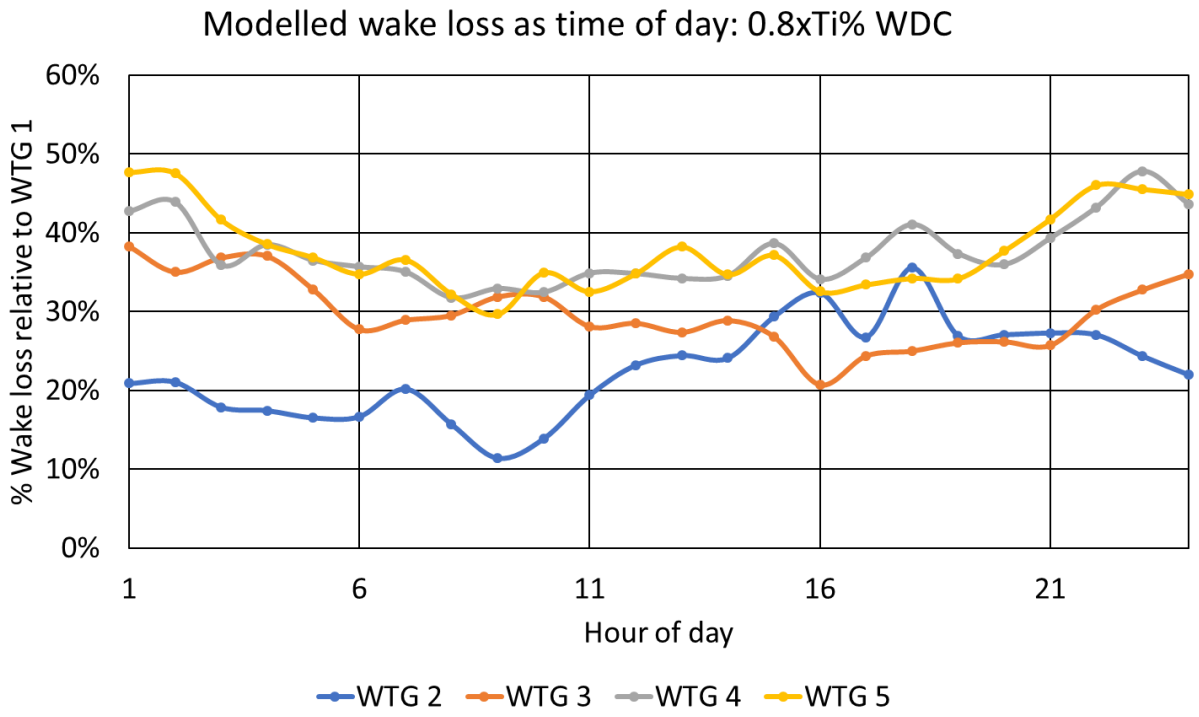
- Following results are based on average of all remaining data after filtering for:
  - Wind speed range 5-10 m/s
  - Wake free direction
  - All 5 turbines concurrently in normal operation mode



EMD International

# Results: Diurnals of Wake Loss



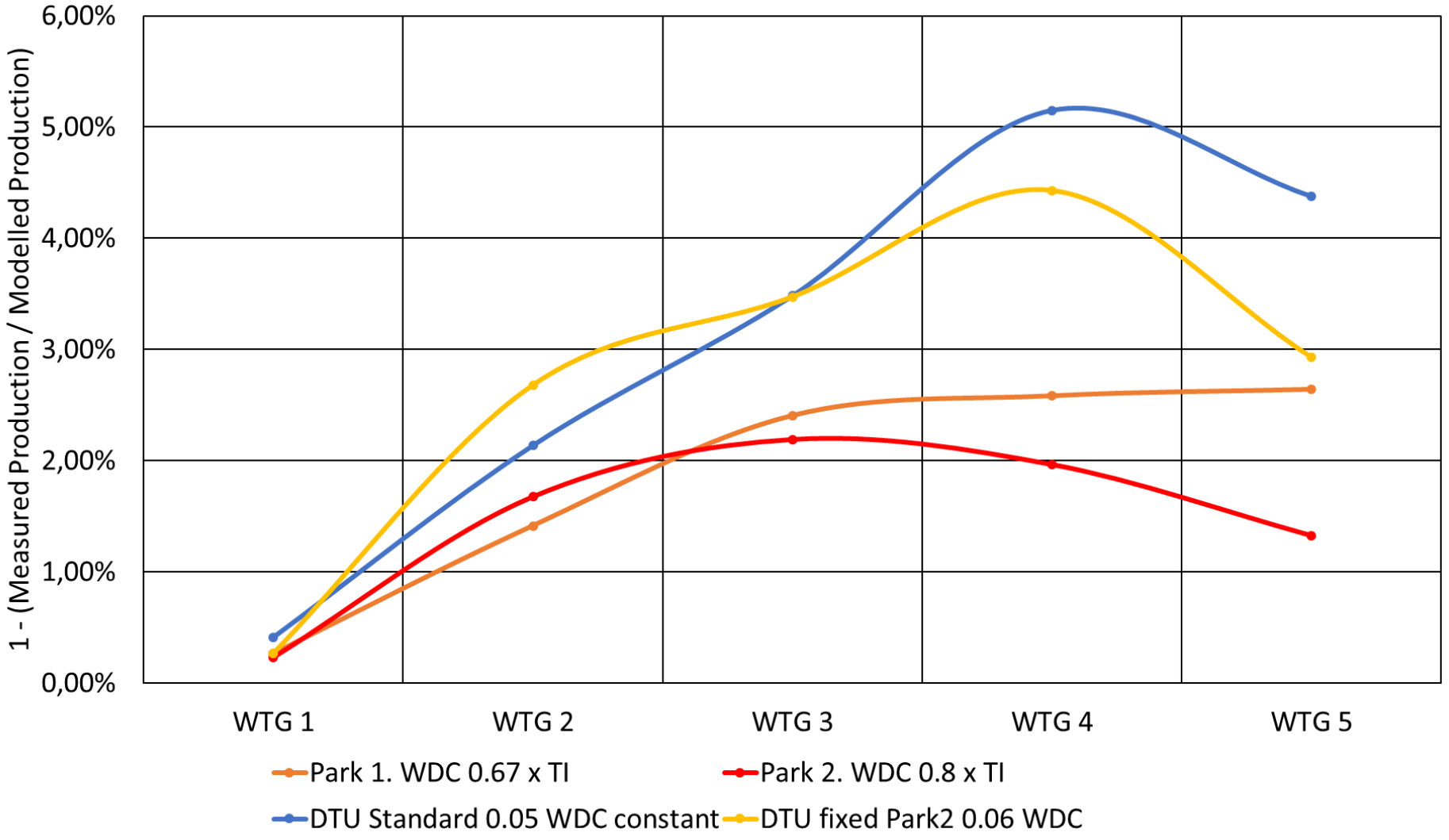




On this site no significant improvement was found when modelling diurnal losses with time-varying WDC as compared to using a fixed WDC.

However, the diurnal TI variation is weak offshore!

**But ...**

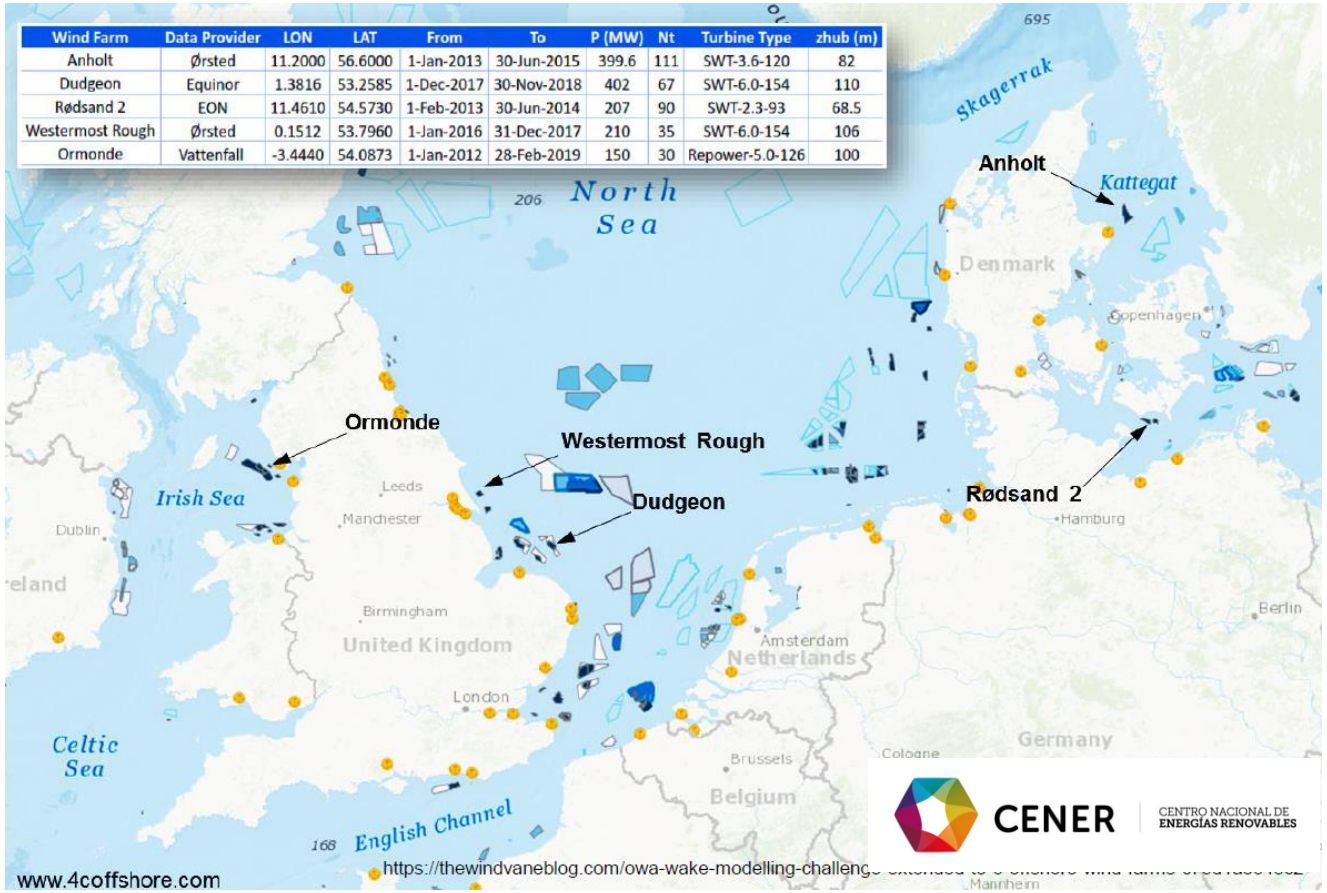
# Results: How well do we get the wake losses right ?




EMD International

# OWA Wake Modelling Challenge - Blind Test

| Wind Farm | Data Provider | LON | LAT | From | To | P (MW) | Nt | Turbine Type | zhub (m) |
|---|---|---|---|---|---|---|---|---|---|
| Anholt | Ørsted | 11.2000 | 56.6000 | 1-Jan-2013 | 30-Jun-2015 | 399.6 | 111 | SWT-3.6-120 | 82 |
| Dudgeon | Equinor | 1.3816 | 53.2585 | 1-Dec-2017 | 30-Nov-2018 | 402 | 67 | SWT-6.0-154 | 110 |
| Rødsand 2 | EON | 11.4610 | 54.5730 | 1-Feb-2013 | 30-Jun-2014 | 207 | 90 | SWT-2.3-93 | 68.5 |
| Westermost Rough | Ørsted | 0.1512 | 53.7960 | 1-Jan-2016 | 31-Dec-2017 | 210 | 35 | SWT-6.0-154 | 106 |
| Ormonde | Vattenfall | -3.4440 | 54.0873 | 1-Jan-2012 | 28-Feb-2019 | 150 | 30 | Repower-5.0-126 | 100 |




PO.165,
next presentation

Setting:

- EMD time-varying NO Jensen Park 2
- EMD time-varying WDC driven by TI

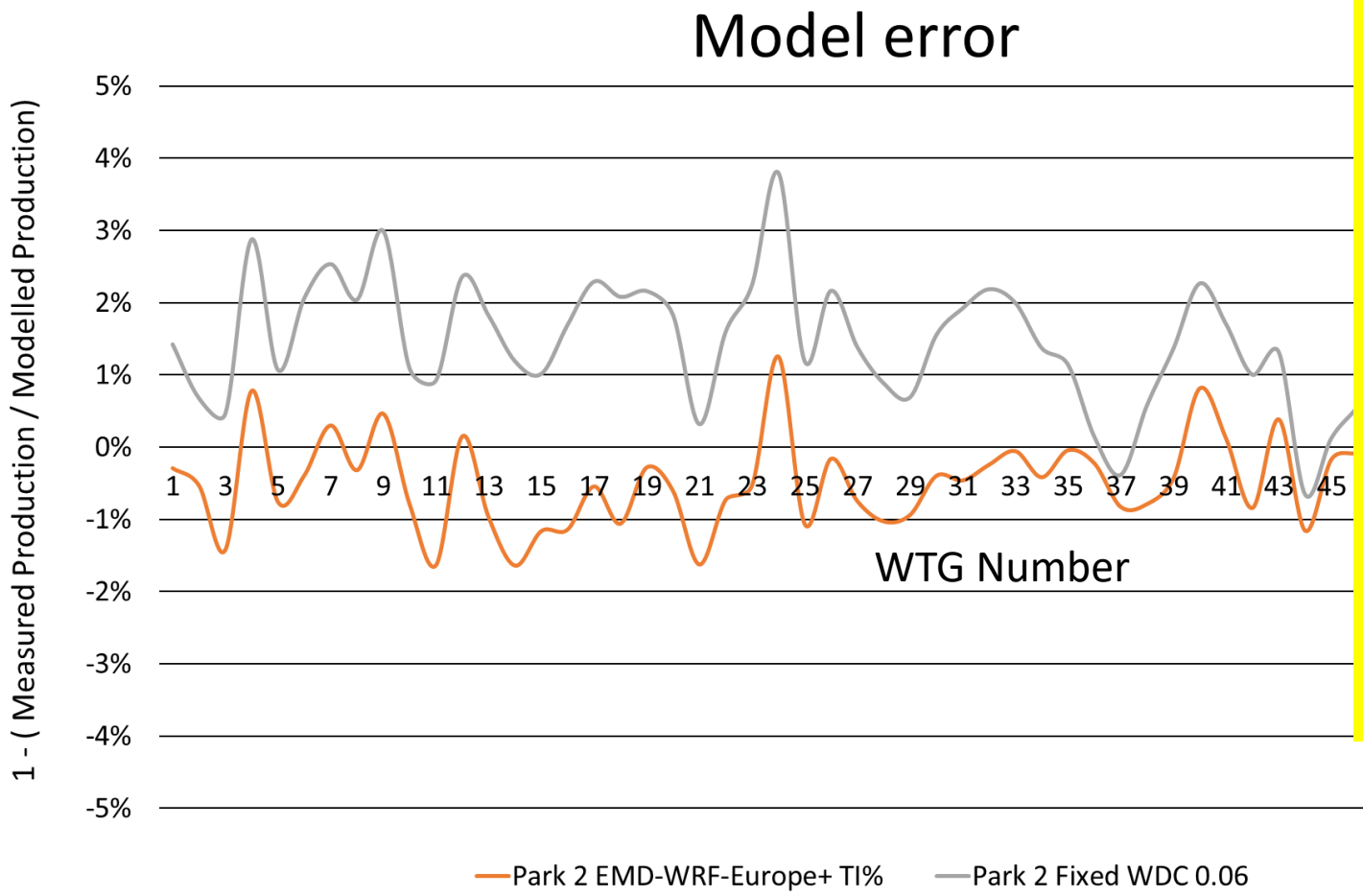
Result:

EMD achieved from all participants

- smallest bias to average
- smallest mean absolute error to the mean

EMD International

# No on-site TI data available? EMD-WRF-Europe+




- Pattern of Production: Park 2 achieves smaller model error across the farm
- Park 2 with time-varying WDC coupled to TI results in absolute numbers in 3.1% higher wake loss.
- The std dev of model error is halved compared to fixed WDC
- Deep array bias removed.
- Need more site for further validation!!!

EMD International

# Conclusion

- With NO. Jensen PARK2 Wake model using time-varying calculation and a WDC = 0.8 x TI, we have seen very precise reproduction of wake losses for numerous offshore wind farms.
- Should no not be Wake Decay “Constant” but a turbulence-dependent variable !!!
- The time-varying WDC model resulted in an overall 2.5% to 3% higher absolute wake loss compared to using the PARK2 DTU default settings (WDC constant = 0.06)
- The wake losses do not change much by hour of day, as offshore we do not see large diurnals of TI compared to onshore.

Contact:
Henrik Sundgaard Pedersen, Senior Wind Consultant
hsp@emd.dk

EMD International