# Do Floating LiDARs qualify for assessing offshore wind turbine power curves?

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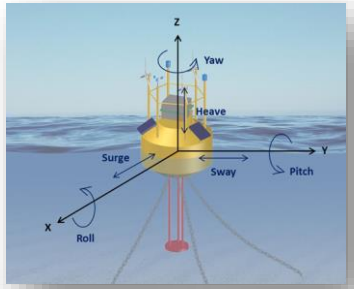
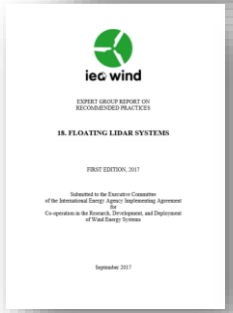
# Outline

- Introduction – why power curve measurements with FLS
- Demonstration field measurement
- FLS technology
- Results for FLS power curve incl. discussion of uncertainties
- Conclusions
- *Outlook: special purpose lidar buoy “MoBo”*

# Introduction

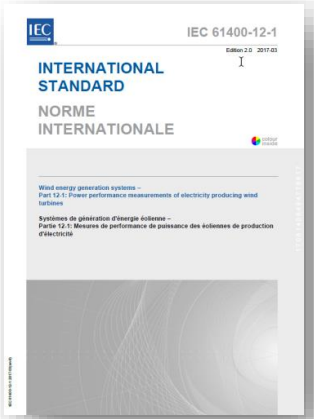
Floating LiDAR (FLS)
(focus on Wind Resource Assessments)





Most recent standard for power curve assessments (acceptance by industry)




Combine both for cost-efficient offshore “FLS Power Curves”

→ maximal compliant with IEC 61400-12-1:2017 (except for stand alone application)





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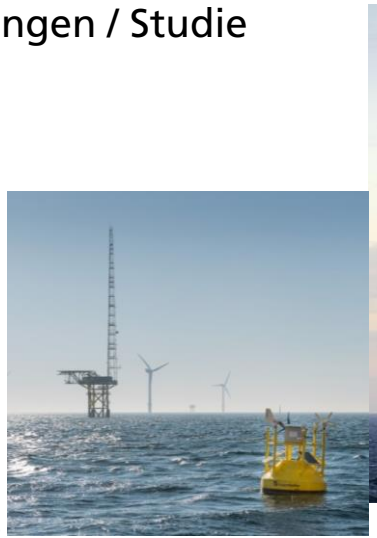
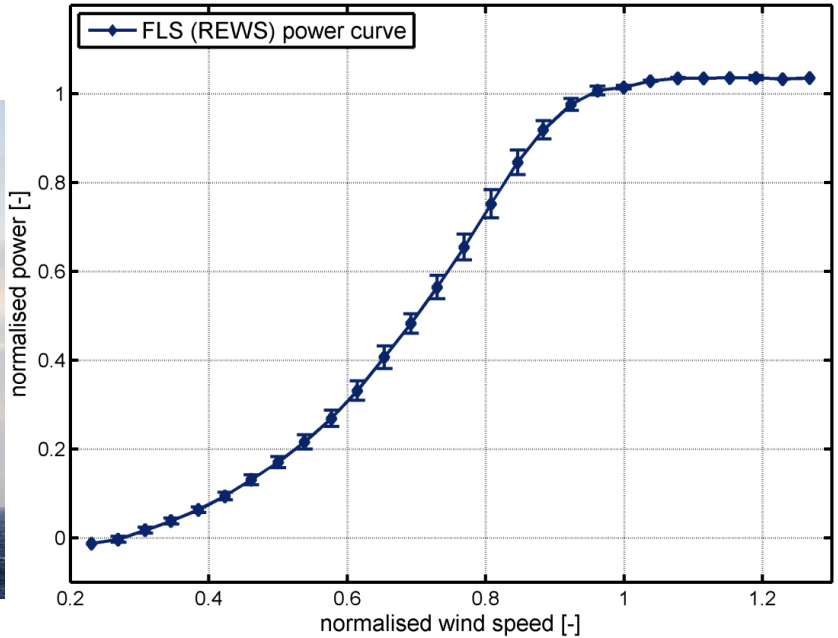
# Flashback: RAVE-interner Workshop (25.01.2018, Bremerhaven)

→ Presentation „Verwendung von RAVE-Daten im Projekt LeikLine – Offshore-Leistungskennlinienvermessung mit einem schwimmenden Lidar-System“

- **LeikLine**: seit Mai 2017 RAVE-Projekt
- vorher (März 2017) externe Datenanfrage … Verwendung von RAVE-Daten für (vorläufige) Auswertungen / Studie

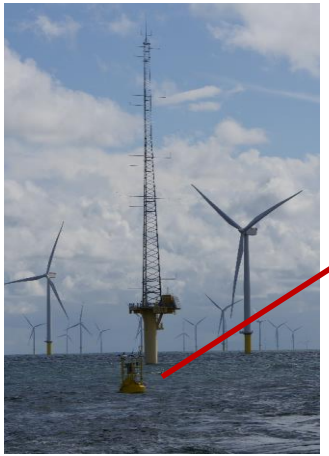


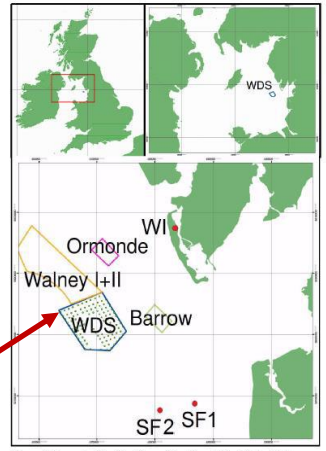
Leistungskennlinienvermessung (AV04)



# Demonstration field measurement

- **Idea:** Offshore power curve measurements for free-flow and wake conditions by FLS
- **Purpose:** Development and demonstration of concept
- **Benefit:** results can be put into standardisation
- **Measurement period:** 6 months
- **Partners**: Ørsted and Iberdrola






- **Project:** LeikLine
- **Funding:** German Federal Ministry for Economic Affairs and Energy (BMWi, FKZ 0324077)

# Technical Details - 1

- LiDAR: ZX Lidar (ZephIR) 300M or Leosphere WINDCUBE
- Dimensions: Overall height 9,2 m, diameter 2.55 m
- Weight: Approx. 5.6 t
- Operational water depth: Min. 15 m
- Material: Steel hull (DIN 1.0036), anodized aluminium for LiDAR housing
- Mooring: DIN 5683-II mooring chain, 3t to 5t concrete sinker (mooring may be adapted to site)

# Technical Details - 2

- Data communication: **WiFi** – *nearby vessel for complete data transfer*
  **GSM/G3/G4** – *onshore / near shore*,
  **Iridium SBD** – *for status data and alarms,*
  **Iridium Pilot/Certus** – *data transfer*
- Primary power system: Autonomous renewable energy-based power system consisting of 6 PV panels (400 Wp) and micro-wind turbines (3 x 400W)
- Secondary power system: Diesel Generator (back up)
- Energy storage: AGM batteries ensure a power supply for one week without further generation

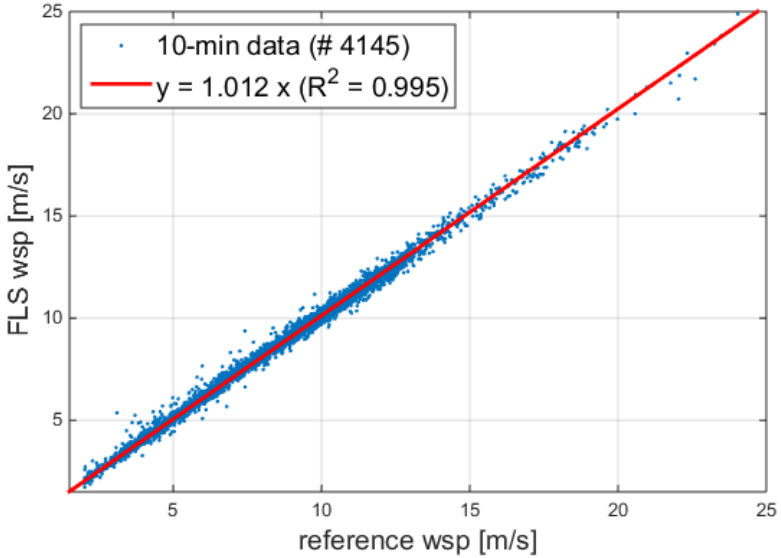
# Accurate by Motion Compensation

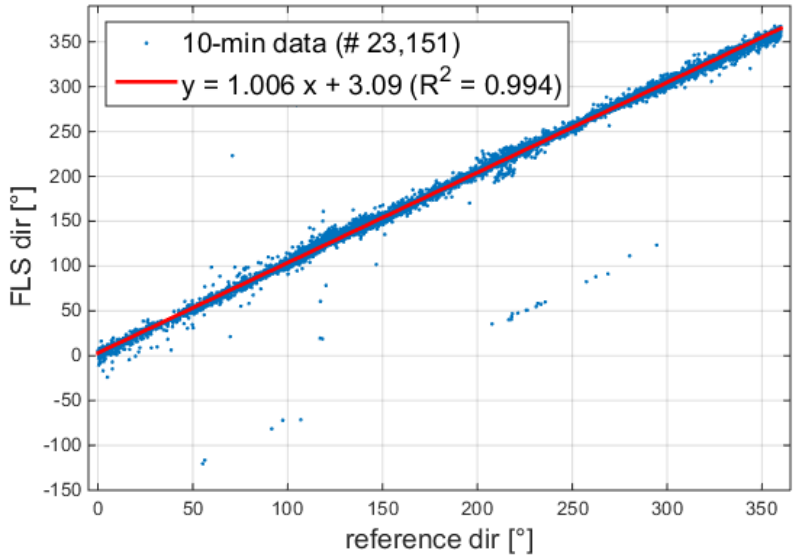
- Software based motion correction for wind speed and direction
- Based on highly resolved motion data and applied to 1 Hz LiDAR data
- Presently implemented as part of post-processing (on-board solution under development)

# FLS technology → offshore verification

**(here: LeikLine measurement campaign at West of Duddon Sands offshore wind farm)**

- Fraunhofer IWES Wind LiDAR Buoy (@ 60 m)





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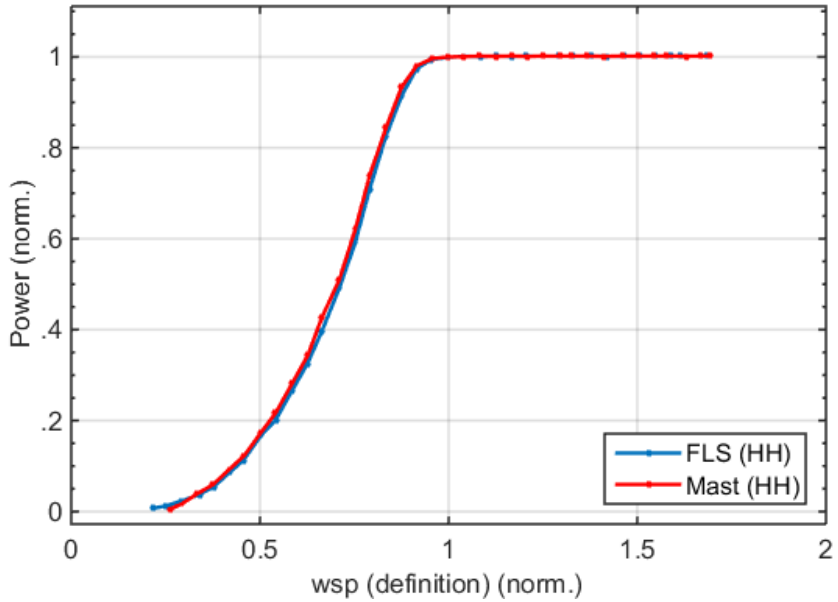
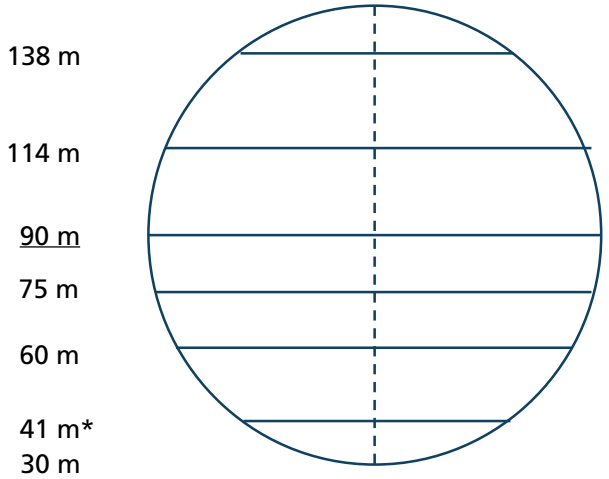
# Results for FLS Power Curve (PC)




⇒ almost identical with Mast PC (for Hub Height wind speed definition)

… but only with FLS REWS (Rotor Equivalent Wind Speed) for whole rotor area (↓)





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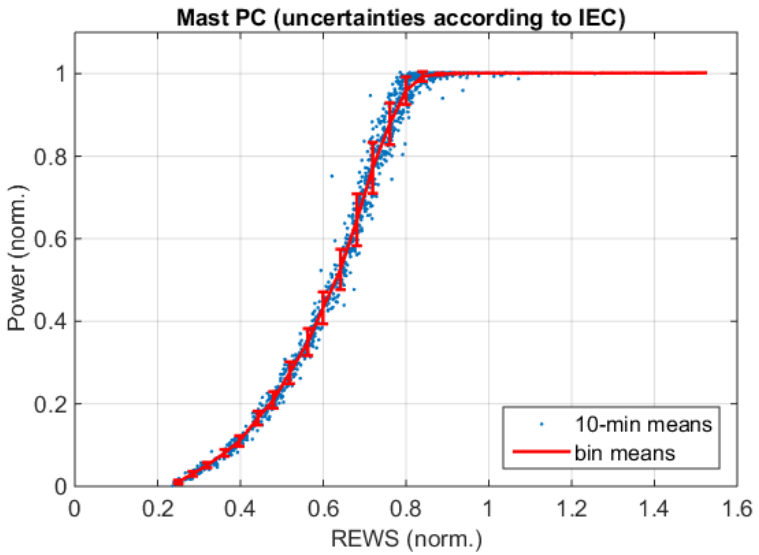
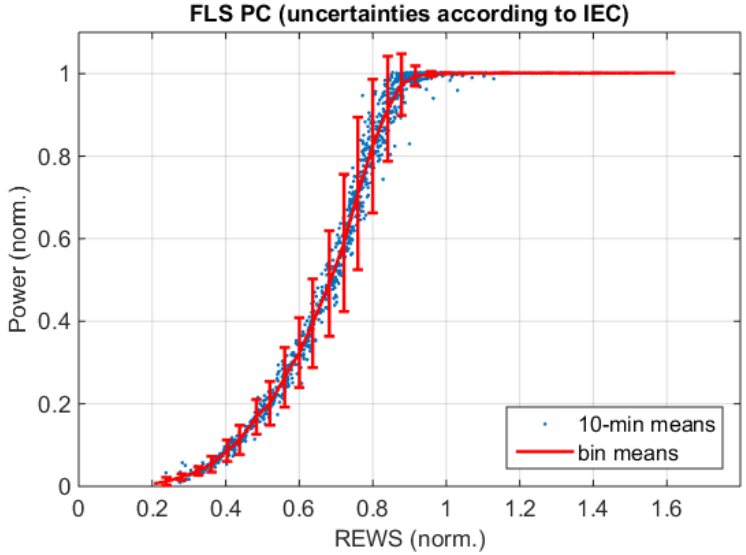
# Results for FLS Power Curve – IEC uncertainties



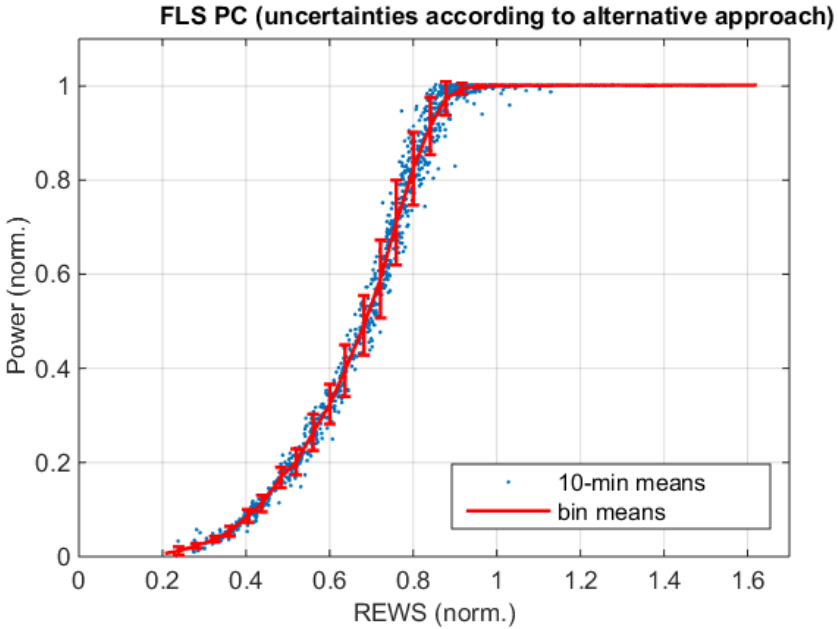

⇒ Deficit of REWS based on mast data (no full rotor coverage) only small impact, additional uncertainties for FLS PC much higher (when following IEC 61400-12-1:2017)

# Discussion of IEC uncertainties

## Why are uncertainties of FLS Power Curve so high?

- cf. OWA LUSR* project results → IEC too conservative assessment of …
  - LiDAR / FLS verification uncertainty (incl. consideration of distance to mast)
  - uncertainty due to terrain and flow complexity
  - mounting uncertainty

⇒ Proposed alternative approach for uncertainty assessment




* OWA Report 2017-001 "Lidar Uncertainty Standard Review Methodology Review and Recommendations", June 2018 (https://www.carbontrust.com/media/676998/owa-w-lusr_nov-2018.pdf)

# Do FLS qualify for assessing offshore wind turbine power curves?

## Yes, they do…

- FLS shows excellent agreement with met mast
- FLS approach makes full use of concept of REWS
  → lowest “method shear / veer” uncertainty components
- FLS can be considered as almost “ground-based”
  → compliance with IEC 61400-12-1:2017
- Practical advantages of FLS
  → turbine-independent wind measurements
  → easy re-deployment

# Do FLS qualify for assessing offshore wind turbine power curves?

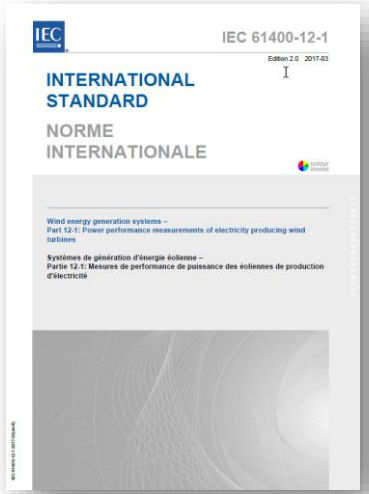
## …but further standarisation necessary

- Uncertainties estimated according to standard are much too high

  → require alternative approach (as suggested within OWA LUSR project).

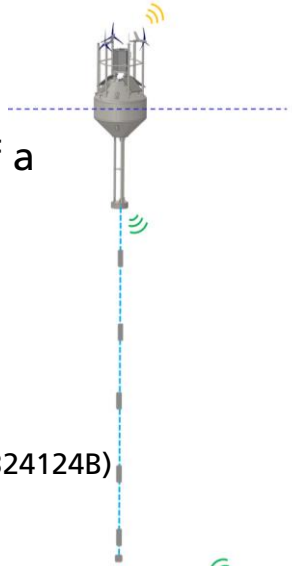
- Stand-alone application of lidars for power curve assessment – as deviation from standard – particularly for offshore

  → next revision of IEC standard




# MoBo: Measurement Buoy for marine monitoring

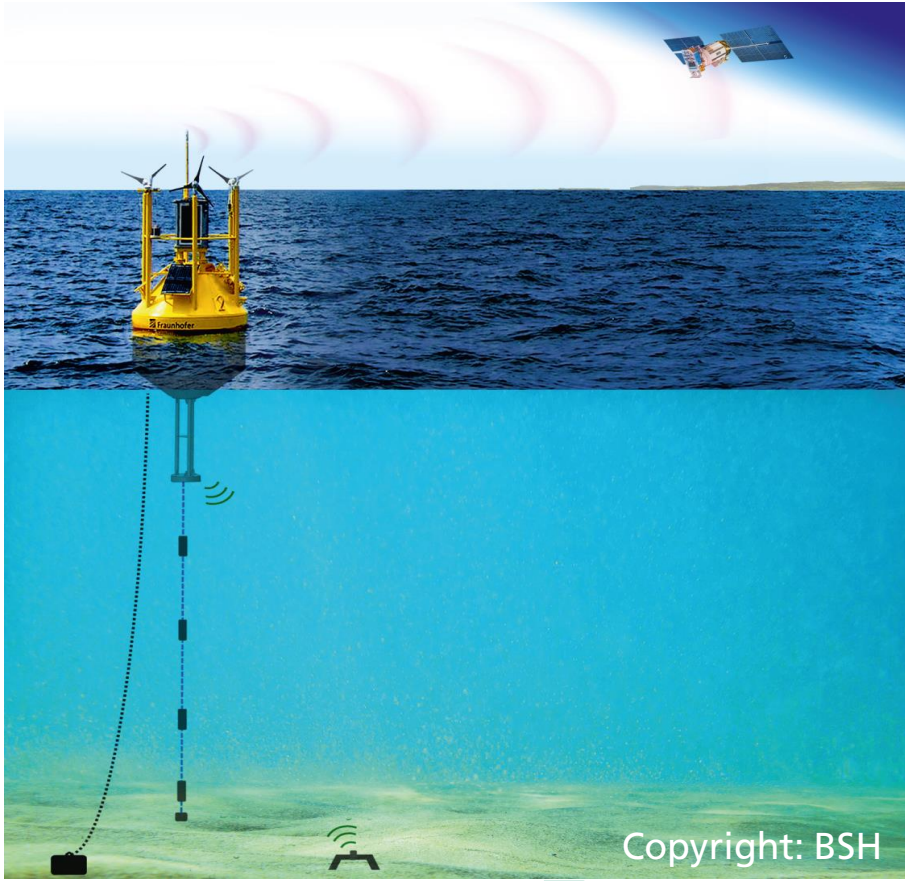
- Research project MoBo in collaboration with the BSH* for the development of a marine monitoring network
- Combination of Wind & Meteorological LiDAR Buoy with underwater measurement chain
- Verification test started November 2019
- Funding: German Federal Ministry for Economic Affairs and Energy (BMWi, FZK 0324124B)



*BSH: Federal Maritime and Hydrographic Agency of Germany

# MoBo: Sketch

- Satellite Communication
- Fraunhofer IWES Wind LiDAR Buoy
  - Wind, pressure, humidity, temperature, etc.
- Buoy Pedestal
  - CTD, pH, etc.
  - ADCP (looking down) for current measurement
- Measurement Chain
  - Multiple CTDs, pH, etc.
- Sea Surface
  - CTD
  - ADCP (facing up) for current measurement



# Thanks a lot for your attention!

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