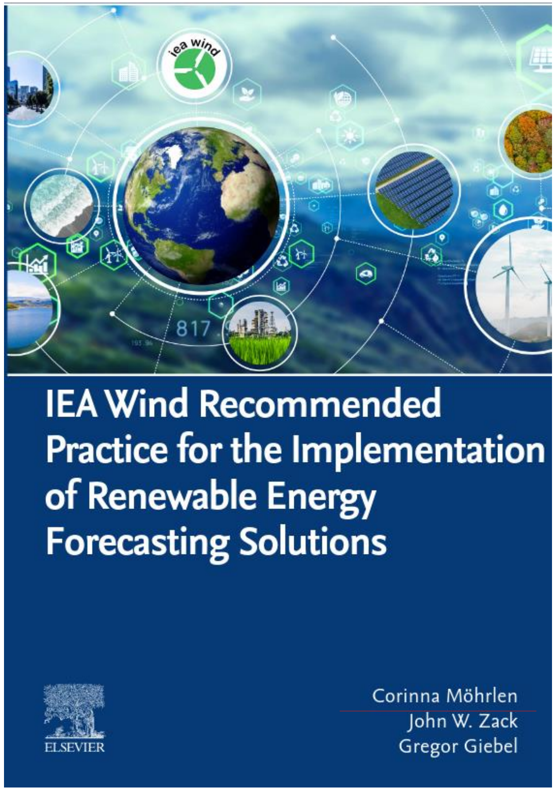
IEA Wind Task 51

IEA Wind Recommended Practice for the Implementation of Renewable energy Forecasting Solutions

WEPROG



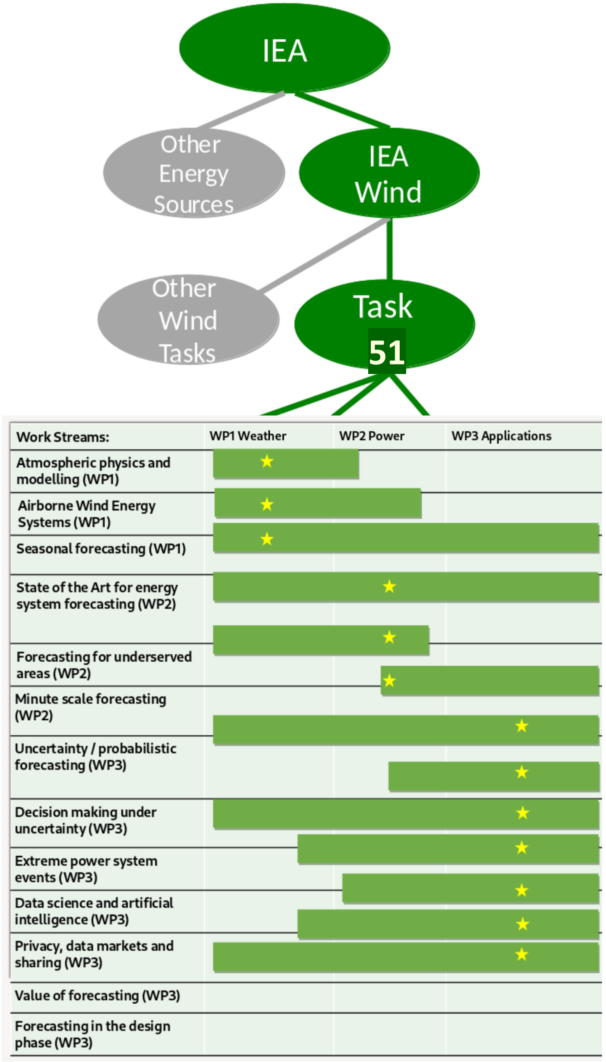
Introduction and Example Performance

Evaluation for met data at Fino & Alpha Ventus

RAVE Workshop Hamburg

11 May 2023

IEA Task 51 - Forecasting for the weather driven Energy System



What is the IEA (International Energy Agency)? (www.iea.org)

- International organization within OECD with 30 members countries and 8 associates
- Promotes global dialogue on energy, providing authoritative analysis through a wide range of publications
- **One activity: convenes panels of experts to address specific topics/issues**

Task 51: Forecasting for the weather driven Energy System:

- One of 17 Tasks of IEA Wind: https://iea-wind.org/
- Task 36: Phase 1: 2016-2018; Phase 2: 2019-2021 **Task 51: Phase 3: 2022-2025**
- Operating Agent: Gregor Giebel of DTU Wind Energy
- Objective: facilitate international collaboration to **improve wind energy forecasts**
- Participants: (1) research organization and projects, (2) forecast providers, (3) policy-makers and (4) end-users & stakeholders

Task 51 Scope: 3 “Work Packages” / 13 “Workstreams”

- WP1: Global Coordination in Forecast Model Improvement
- WP2: Benchmarking, Predictability and Model Uncertainty
- WP3: Optimal Use of Forecasting Solutions

Task homepage: https://iea-wind.org/task51

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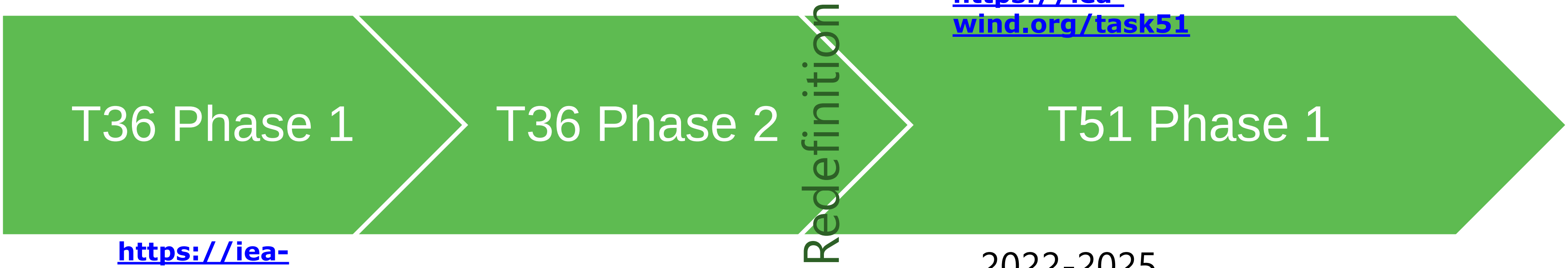
Forecasting for Wind Energy

2016-2018

2019-2021

https://iea-wind.org/task51



https://iea-wind.org/task36

2022-2025

Forecasting for the Weather Driven Energy System

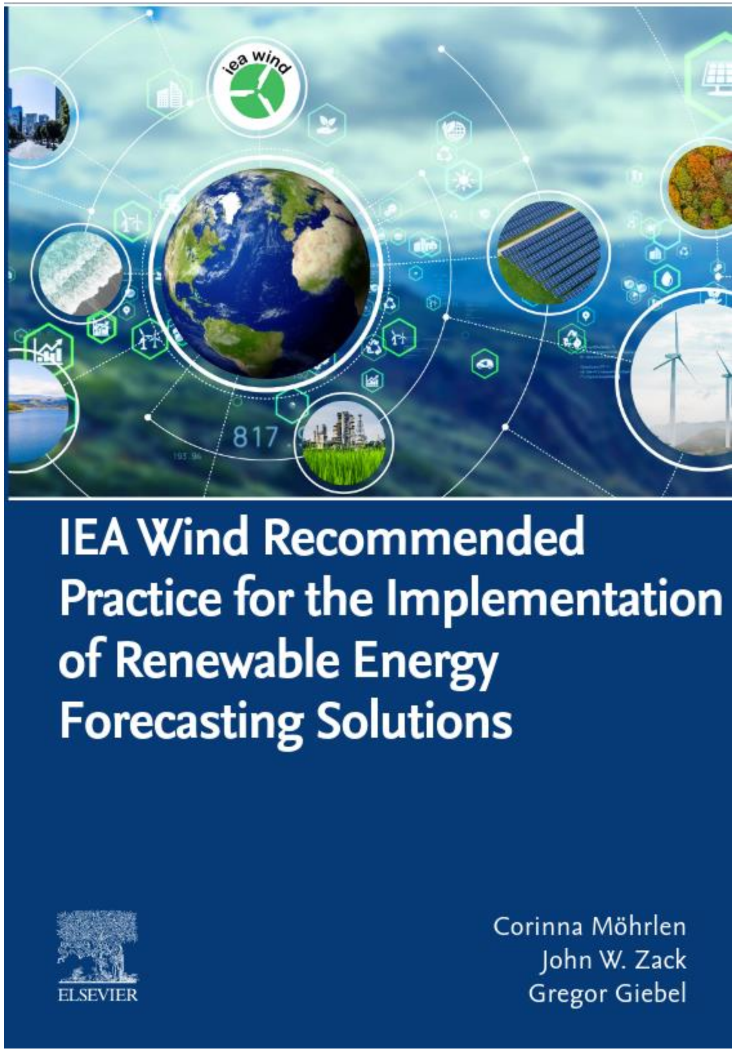
Recommended Practice Book

Note

Elsevier Book
https://www.elsevier.com/books/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions/mohrlen/978-0-443-18681-3

Online OpenAccess:
https://www.sciencedirect.com/book/9780443186813/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions

IEA Wind Task 51 Information
iea-wind.org → Task 51 → Publications → Recommended Practice



IEA Wind Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions: Set of 4 Parts

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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 1: FORECAST SOLUTION SELECTION PROCESS -

2. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 1: Selection of an Optimal Forecast Solution

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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS -

2. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 2: Design and Execution of Benchmarks and Trials

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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 3: Forecast Solution Evaluation -

2. EDITION

Draft for Review by Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 3: Evaluation of Forecasts and Forecast Solutions

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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 4: Meteorological and Power Data Requirements for real-time forecasting Applications-

1. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 4: Data Requirements for Real-time Applications

Video Introduction

Introduction: https://www.youtube.com/watch?v=XVO37hLE03M

Summary & Introduction of the IEA Wind Recommended Practice for the Implementation of Renewable Energy Forecasting - Part 4:

Meteorological Data Requirements to be provided in the grid codes for real-time forecasting models

Data Requirements to be provided in the grid codes for real-time forecasting models

- BACKGROUND -

Combination of **actual wind measurements + trend from wind forecast** provide necessary input to a number of areas in grid operation: e.g.

- forecast of high-speed shut-down events
- strong ramping events
- potential power computation
- compensation for curtailments
- etc.

Currently every ISO/TSO has to develop their own requirements for the grid code

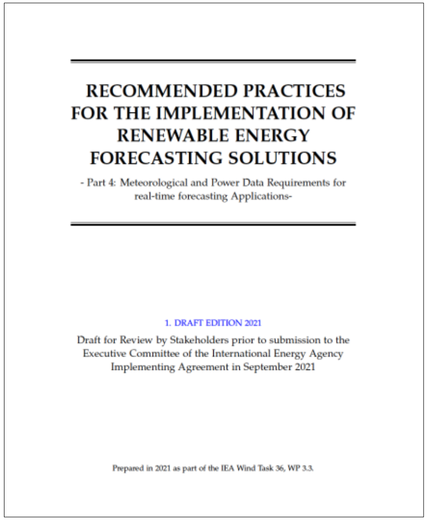
→ a industry guideline would make this process much more efficient!

Part 4: Meteorological and Power Data Requirements For Real-time Forecasting Applications

Target: Provide guidance for deploying and operating on-facility meteorological sensors to gather data for input into renewable power forecasts

Content:

1. Background and Objectives
2. Meteorological Instrumentation for Real-Time Operation
3. Power Measurements for Real-time Operation
4. Measurement Setup and Calibration
5. Assessment of Instrumentation Performance
6. Best Practice Recommendations
7. Examples of System Operator Measurement Requirements



RECOMMENDED PRACTICES FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 4: Meteorological and Power Data Requirements for real-time forecasting Applications-

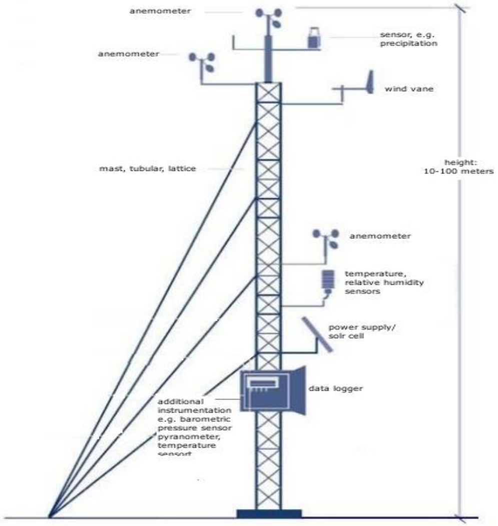
1. DRAFT EDITION 2021

Draft for Review by Stakeholders prior to submission to the Executive Committee of the International Energy Agency Implementing Agreement in September 2021

Prepared in 2021 as part of the IEA Wind Task 36, WP 3.3.

Review of instrumentation and industry Best Practice

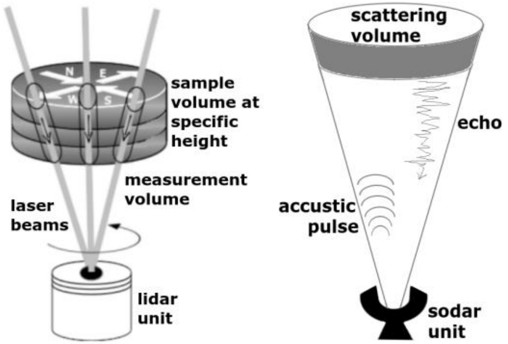
Meteorological Mast



Well known and tested

Standards for instruments

Remote Sensing Instruments

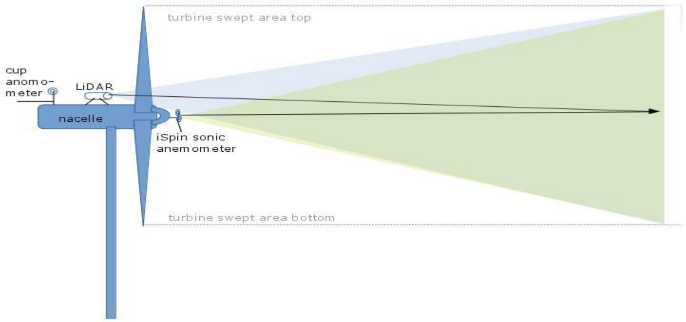


Less known in Wind Applications

Meteorologically interesting

Standards need to be adjusted for wind applications

Nacelle Instruments



Relative new application

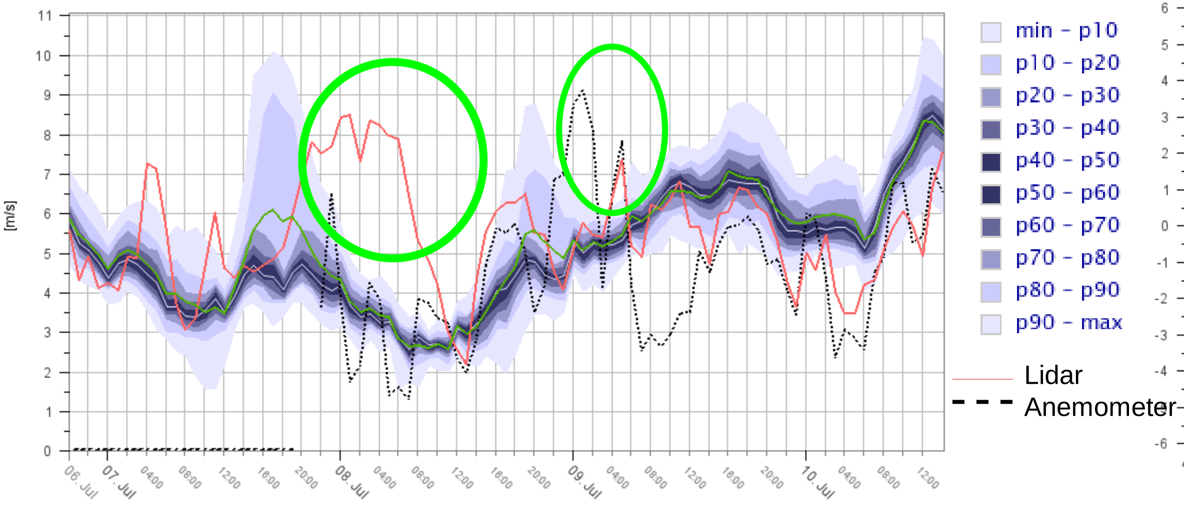
"old" technology (cup anemometer) insufficient

advantages not tested for forecasting/grid security

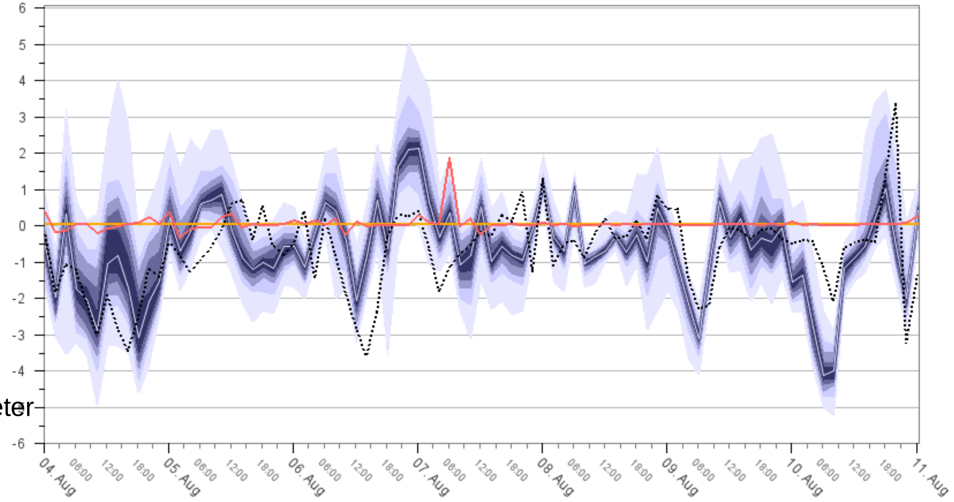
Findings from analysis of different measurement types in real-time environments

Many remote sensing instruments are mature for real-time Operation - some require more testing and pilots…

Just 2 typical challenging situations in a quality analysis...



Outliers on both Metmast & Lidar…



Difference between anemometer and Lidar is equal to difference to forecast

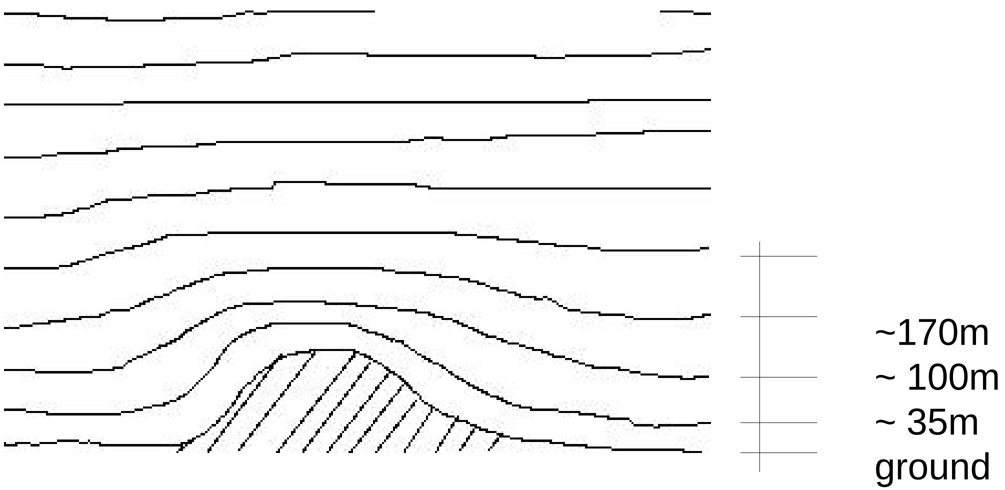
Recommendations for Met Data Requirements for real-time wind forecasting

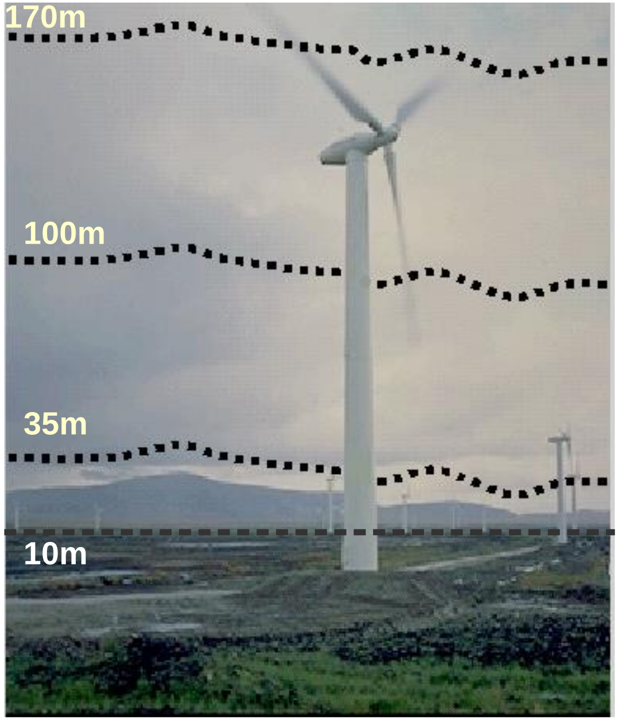
Requirement suggestions for wind farm accuracy of measurement instrumentation

Measurement	Units	Precision for Instantaneous Measurements (to the nearest…)	Range	Accuracy	Required /Optional
Wind Speed	Meters/Second (m/s)	0.1 m/s	0 to 50	±1m/s	R
Wind Direction	Degrees from True North	1 degree	0 to 360	±5°	R
Surface Pressure	HectoPascals (HPa)	1 hPa	800-1100	± 1.0 hPa at -20 … 45 °C	R
Temperature	Degree Celsius	0.1° C	-50 to +50	±0.2 K in the range -27 … +50°C	R
Dewpoint	Degrees Celsius (°C)	0.1° C	-50 to +50	±0.2 K in the range -27 … +50°C	O
Relative Humidity	Percentage (%)	1.00%	0 to 100 %	±2% RH in the range 5- 95% RH at 10-40°C	O
Ice-up Parameter	Scale 0.0 to1.0	0.1	0 to 1	n/a	O/R
Precipitation	mm/min	0.1	0-11	2% until 25 mm/h 3% over 25 mm/h	O

Representativeness of measurements and fit to real-time NWP Forecasting

Background information about the relevance of measurement heights for the weather models





Lowest 3-4 model levels are always in the range
30-40|90-100|170-180m
→ common for all NWP models

Downscaling from model levels usually better than up-scaling from 10m wind!
→ 10m wind is a standardised, but calculation method for fixed heights

Quality control of meteorological measurements in the real-time environment:
Assessment of instrumentation performance

- **Measurement data processing**

- **Uncertainty expression in measurements**
  ➔ Known issues of uncertainty in specific instrumentation
  ➔ Effects of uncertainty in nacelle wind speed measurements and mitigation methods
  ➔ Application of nacelle wind speeds in real-time NWP data assimilation

- **General data quality control and quality assurance (QCQA)**
  ➔ Historic quality control (QC)
  ➔ Real-time quality control (QC)
  ➔ Data screening in real-time wind and solar forecast applications
  ➔ Data sampling thresholds in real-time wind and solar forecast applications

Quality control of meteorological measurements in the real-time environment:

Recommended Principles for the Selection of Instrumentation

The recommendations for the selection of instrumentation based on the following set of principles:

1. Accuracy requirements:

Accuracy requirements need to be defined for the application/project and aligned with the associated levels of effort necessary to operate and maintain the measurement system on under these constraints. An overall cost-performance determination should therefore always be carried out to adapt the budget to the accuracy requirements and vice versa.

2. Reliability requirements:

Reliability can be achieved with redundant instrumentation and/or high quality instrumentation. Redundancy enhances and ensures confidence in data quality. Selection of multiple instruments need to be aligned with the accuracy needs.

Quality control of meteorological measurements in the real-time environment:

Recommended Principles for Wind Power Performance Control

Performance control of wind farms and wind turbines is best conducted in the following 3–4 steps:

a) Measuring basic meteorological parameters that can be used to compute power generation output

- wind speed and direction
- air temperature
- barometric pressure
- relative humidity

b) Conversion of the meteorological parameters into a power output

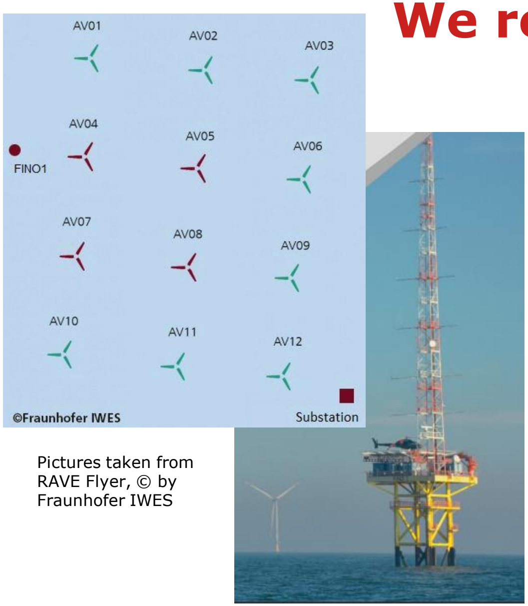
The best and recommended way is the IEC 61400-12-1 standard on power performance measurements, which is based on a physical formula (Equ. 2, chapter 8 [142])

c) Comparison of power output with measured and forecasted input variables

d) Visual Inspection with Ensemble generated Percentiles

Example Alpha Ventus + Fino1: Quality control of meteorological measurements in the real-time environment

We reverse verification: measurement versus forecasts!



Pictures taken from RAVE Flyer, © by Fraunhofer IWES

Variable list and their threshold error limits

Var Number	Variable Name	Mininum Correlation	Maximum |Bias|	Maximum MAE
1	WindSpeed	0.65	3.0	3.0
2	AirTemp	0.75	2.0	2.5
3	WindDirection	0.55	13.0	20.0
4	AirPressure	0.9	50.0	85.0

Exemplary results from the Quality analysis of 6 Turbines & UW

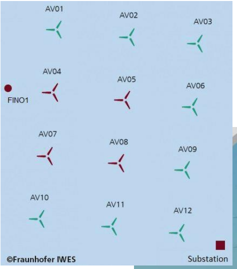
Statis-tic rank	Windfarm ID	Test: ws|temp|wd|ps	wind speed WS	temp-erature T	wind direction WD	surface pressure PS	Description
1	AV07	1111	111	111	111	111	all tests ok
2	AV08	1111	111	111	111	111	all tests ok
3	UW	1110	111	111	111	000	PS fails all tests
4	AV09	1101	111	111	100	111	WD fails, except for WD(BIAS) OK
5	AV10	1101	111	111	101	111	WD fails, except for WD(MAE) OK
6	AV11	1010	111	000	111	110	T fails on all
7	AV12	1001	111	000	101	111	T fails and WD(MAE) fails

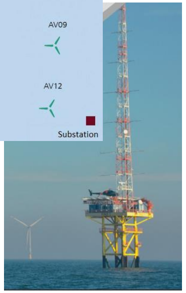
Criteria for "goodness" of data

Variable	unit	lower Limit	upper Limit
Wind speed (WS)	m/s	0	40
Wind direction (WD)	deg	0	360
Temperature (T)	°C	-40	40
Surface pressure (PS)	hPa	800	1100

Fino data: Wind, Temperature and Pressure
Turbines/UW: Wind & Power

Example Alpha Ventus +Fino1: Quality control of meteorological measurements in the real-time environment: Recommended test for met data performance control





Pictures taken from RAVE Flyer, © by Fraunhofer IWES

	STATISTICS								
ID Period	PART 1 (ws,T2m,wdir,ps)	WindSPEED (bias, rmse,corr Realistic values)	Temperature (bias, rmse,corr Realistic values)	WindDIR (bias, rmse,corr Realistic values)	Pressure (bias, rmse,corr Realistic values)	Installed Capacity [MW]	Improve-ment >5%	Delivery Rate [%]	BIT MASK
Good DATA									
2021q3 WAVUWT001	1111	1111	1111	1111	1111	60.0	2.19	99.8	15
capacity						60			
Bad DATA || MiSSING DATA + Delivery < 98.5%									
2021q2 WAVM8T001	1001	1111	0001	0001	1111	5.0	6.57	10.6	9
WAVM7T001	1001	1111	0001	0001	1111	5.0	6.14	11.4	9
capacity						10.0			
Bad Data || Missing data + Requirement 2: Improvement < 5%									
2021q1 WAVM7T001	0101	0111	1111	1001	1111	5.0	0	47.7	10
capacity						5.0			

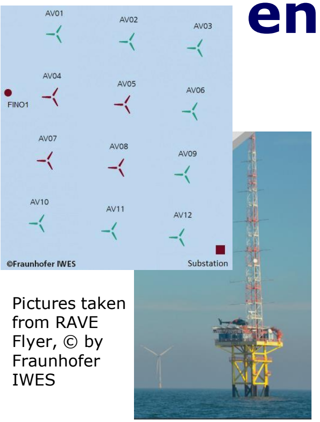
Explanation of Available/missing Variables:

0 or -	bad/missing
1	windspeed (ws)
2	temperature (T)
3	ws+temperature
4	wind direction (wd)
6	wd + T
8	pressure (ps)
5	ws+ps
10	T+ps
11	ws+T+ps
12	wd+ps
13	ws+wd+ps
14	T+wd+ps
15	all variables delivered

1=ok, 0=bad, "-"=missing

Explanation of columns WS||WDIR||TEMP||PS	
1	BIAS
2	RMSE
3	CORR
4	data delivery of realistic values
1=ok, 0=bad, "-"=missing	

Example Alpha Ventus +Fino1: Quality control of meteorological measurements in the real-time environment: Test 1 for met data performance control



Pictures taken from RAVE Flyer, © by Fraunhofer IWES

2021q3	STATISTICS					CHARACTERISITCS					
ID Period	PART 1 (ws,T2m, wdir,ps)	WindSpeed (bias, rmse,corr Realistic values)	Temperature (bias, rmse,corr Realistic values)	WindDIR (bias, rmse,corr Realistic values)	Pressure (bias, rmse,corr Realistic values)	Installed Capacity [MW]	MAE obs	MAE Fc	Improve-ment >3%	Delivery Rate [%]	BIT MASK
WAVUWT001	1011	1111	1101	1111	1111	60	0.91	0.82	2.74	95.9	13
WAVM7T001	1001	1111	0001	0001	1111	5	1.14	1.17	5.87	11.5	9
WAVM8T001	1001	1111	0001	0001	1111	5	1.15	1.17	6.43	10.7	9
WAVM9T001	0001	0001	0001	1101	1111	5	0.98	0.98	0.00	9.9	8

Explanation of Available/missing Variables:

0 or -	bad/missing
1	windspeed (ws)
2	temperature (T)
3	ws+temperature
4	wind direction (wd)
6	wd + T
8	pressure (ps)
5	ws+ps
10	T+ps
11	ws+T+ps
12	wd+ps
13	ws+wd+ps
14	T+wd+ps
15	all variables delivered

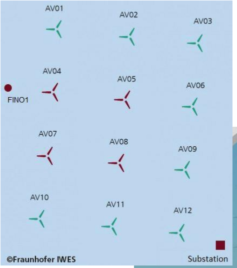
1=ok, 0=bad, “-”=missing

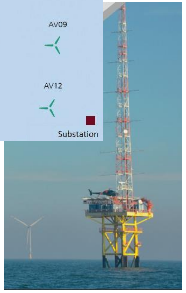
2021q3		
ID Period	Avail Active Power	MW
WAVUWT001	12701	0
WAVM7T001	1519	0
WAVM8T001	1413	0
WAVM9T001	1309	0

Test1: 1 quarter of 2021
- wind from wind turbines
- power from turbines M7-M12
- power from power station (Umspannwerk, UW) and wind from FINO1

Explanation of columns WS||WDIR||TEMP||PS	
1	BIAS
2	RMSE
3	CORR
4	data delivery of realistic values
1=ok, 0=bad, “-”=missing	

Example Alpha Ventus +Fino1: Quality control of meteorological measurements in the real-time environment:
Test 1 for met data performance control





Pictures taken from RAVE Flyer, © by Fraunhofer IWES

TEST 1 **wind from nacelle anemometers for turbines M7-M12**

	STATISTICS					CHARACTERISITCS					
ID Period	PART 1 (ws,T2m, wdir,ps)	WindSpeed (bias, rmse,corr Realistic values)	Temperature (bias, rmse,corr Realistic values)	WindDIR (bias, rmse,corr Realistic values)	Pressure (bias, rmse,corr Realistic values)	Installed Capacity [MW]	MAE Obs [% inst. Cap]*	MAE Fc [% inst. Cap]*	Improve-ment >3%	Delivery Rate [%]	BIT MASK
2020q4											
WAVUWT001	1111	1111	1111	1111	1111	60	14.1	13.7	1.7	99.8	15
WAVM7T001	1101	1111	1111	1001	1111	5	14.5	12.6	4.6	48.9	11
WAVM8T001	1101	1111	1111	0001	1111	5	14.5	12.1	5.1	22.5	11
2021q1											
WAVUWT001	1111	1111	1111	1111	1111	60	15.2	14.2	3.6	99.4	15
2021q2											
WAVUWT001	1111	1111	1111	1111	1111	60	16.3	14.5	2.2	99.8	15
2021q3											
WAVUWT001	1011	1111	1101	1111	1111	60	16.1	14.4	2.7	95.9	13
WAVM7T001	1001	1111	0001	0001	1111	5	14.5	12.5	5.9	11.5	9
WAVM8T001	1001	1111	0001	0001	1111	5	14.5	12.6	6.4	10.7	9

* statistics for power generated with wind from obs/fc

Explanation of Available/missing Variables:

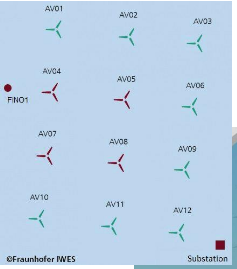
0 or -	bad/missing
1	windspeed (ws)
2	temperature (T)
3	ws+temperature (T)
4	wind direction (wdir)
6	wd + T
8	pressure (ps)
5	ws+wdir
9	ws+ps
10	T+ps
11	ws+T+ps
12	wd+ps
13	ws+wd+ps
14	T+wd+ps
15	all variables delivered

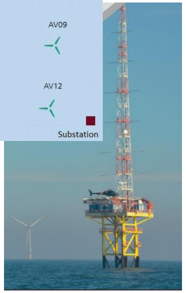
ID Period	Avail Active Power	MW
#2020q4		
WAVM7T001	6478	0
WAVUWT001	13219	0
WAVM8T001	2978	0
WAVUWT001	12886	0
#2021q1		
WAVM7T001	6074	106
#2021q2		
WAVUWT001	13074	0
#20201q3		
WAVUWT001	12701	0
WAVM7T001	1519	0
WAVM8T001	1413	0

Test 1: Oct. 2020 – Sept. 2021
- wind from wind turbines
- power from turbines M7-M12
- power from power station (Umspannwerk, UW) and wind from FINO1

Explanation of columns WS||WDIR||TEMP||PS	
1	BIAS
2	RMSE
3	CORR
4	data delivery of realistic values
1=ok, 0=bad, “-”=missing	

Example Alpha Ventus +Fino1: Quality control of meteorological measurements in the real-time environment: Test 2 for met data performance control





Pictures taken from RAVE Flyer, © by Fraunhofer IWES

Test 2	wind from FINO metmast - power from turbines M7-M12										
	STATISTICS					CHARACTERISITCS					
ID Period	PART 1 (ws,T2m,wdir,ps)	WindSpeed (bias, rmse,corr Realistic values)	Temperature (bias, rmse,corr Realistic values)	WindDIR (bias, rmse,corr Realistic values)	Pressure (bias, rmse,corr Realistic values)	Installed Capacity [MW]	MAE obs	MAE Fc	Improve-ment >3%	Delivery Rate [%]	BIT MASK
2020q4											
WAVM8T001	1111	1111	1111	1111	1111	5.0	15.1	14.04	3.36	22.5	15
WAVM7T001	1111	1111	1111	1111	1111	5.0	15.6	14.54	3.69	48.9	15
2021q1											
WAVM7T001	1111	1111	1111	1111	1111	5.0	15.04	14.04	3.18	47.7	15
2021q2											
WAVM7T001	1111	1111	1111	1111	1111	5.0	15.04	14.04	3.18	47.7	15
2021q3											
WAVUWT001	1011	1111	1101	1111	1111	60.0	16.1	14.415	2.74	95.9	13
WAVM9T001	1011	1111	0001	1111	1111	5.0	14.54	14.1	4.44	9.9	13
WAVM8T001	1011	1111	0001	1111	1111	5.0	14.54	14.1	5.54	10.7	13
WAVM7T001	1011	1111	0001	1111	1111	5.0	14.54	14.6	4.70	11.5	13
WAVM10T001	1001	1111	1101	1011	1111	5.0	14.54	14.6	5.12	35.2	9

Explanation of Available/missing Variables:

0 or -	bad/missing
1	windspeed (ws)
2	temperature (T)
3	ws+temperature
4	wind direction (wd)
6	wd + T
8	pressure (ps)
5	ws+ps
10	T+ps
11	ws+T+ps
12	wd+ps
13	ws+wd+ps
14	T+wd+ps
15	all variables delivered

1=ok, 0=bad, "-"=missing

ID Period	Avail Active Power	MW
#site	AAPcnt	MWcnt
#2020q4		
WAVM8T001	2978	0
WAVM7T001	6476	0
#2021q1		
WAVM7T001	6186	0
#2021q2		
WAVM7T001	6186	0
#2021q3		
WAVUWT001	12701	0
WAVM9T001	1311	0
WAVM8T001	1413	0
WAVM7T001	1519	0
WAVM10T001	4660	0

Test2: Oct. 2020 – Sept. 2021
- turbine power and wind from nacelle anemometers at turbines
- power from power station (Umspannwerk, UW) and turbines M7-M12

Explanation of columns WS||WDIR||TEMP||PS	
1	BIAS
2	RMSE
3	CORR
4	data delivery of realistic values
1=ok, 0=bad, "-"=missing	

Requirements for met measurements in wind energy related real-time environments: SUMMARY

Met data performance control provides important overview of critical parameters for real-time applications:

- robustness of instrument (delivery rate)
- reliability of data from instrument (power analysis)
- representativeness of data from instrument (improvement over forecast)

Application Areas for the Recommendations:

1. System Operation, Balancing and Trading

- Situational awareness in critical weather events
- High-Speed Shutdown events
- Grid related down-regulation or curtailments
- Short-term forecasting with updates from measurements
  - • Intra-day power plant balancing

2. Wind Turbine, Wind Farm and Solar Plant Operation and Monitoring

- Wind turbine and Power Plant Control
- Condition Monitoring

Next Steps & Plans

IEA Wind Task 51 Workstream 7 – Uncertainty Chain
Quantification of Uncertainty throughout the entire modelling chain

IEC SC8A Working Group - Grid Integration of Renewable Energy Generation
→ after Technical Report in 2019 now "new work item proposal" for a standard
→ IEA Wind Recommended Practice is blueprint for the standard

German research project on it's way to use spatially extended information from new satellite data and ensemble forecasts for a better understanding of weather situations critical for offshore wind integration into the grid

The combination of <u>long-term</u> weather and power data at FINO + ALPHA VENTUS are an important test facility due to the otherwise commercial handling of wind industry data (in Germany)...

THANK YOU FOR YOUR ATTENTION

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Contact us…

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